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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 607

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER June 7, 1918

TESTS OF THE ABSORPTION AND PENETRATION OF COAL TAR AND CREOSOTE IN LONGLEAF PINE

By

CLYDE H. TEESDALE, in charge, Section of Wood Preservation, and
J. D. MacLEAN, Assistant Engineer in Forest Products
Forest Products Laboratory, Madison, Wis.

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INTRODUCTION.

One of the most important questions in the preservative treatment of wood is the cost of the preservative. Particularly is this true when creosote is used, and anything which will tend to reduce the cost of this preservative without decreasing its efficiency will be a direct aid to the industry. The use of tar and creosote mixtures in the preservative treatment of wood has increased rapidly in recent years, particularly in the treatment of wood paving blocks. This is due largely to the fact that the tar and creosote mixtures can be produced more cheaply than can creosote containing no tar. There are two other factors, however, aside from cost which must be considered as affecting the use of tar and creosote mixtures. A preservative treatment, to be effective, should show good absorption and penetration and the preservative must be toxic to wood-destroying fungi.[1]

This paper reports the results of an investigation into the effect of tar in creosote upon absorption and penetration of the preservative. The study was made at the Forest Products Laboratory, maintained by the Forest Service, United States Department of Agriculture, in cooperation with the University of Wisconsin at Madison, Wis.[2]

[1] In general the toxicity of tar and creosote mixtures is sufficient to warrant their use in preservatives. Toxicity of wood preservatives is discussed in Bulletins 155 and 227 of the Department of Agriculture.

[2] Acknowledgments are made to Mr. F. M. Bond, formerly of the Forest Service, under whose direction a portion of this work was done.

The most important variables in the treatment of wood affecting absorption and penetration are: (1) The species, character, and condition of the wood; (2) the properties of the oil; and (3) the methods of treatment. To eliminate the variability due to species, and reduce that due to the character and condition of the wood, the experiments were confined to wood of one species (longleaf pine), and so far as possible specimens of uniform quality were selected. This made more readily determinable the relative importance of variations in the oil and in methods of treatment.

The relative absorptions and penetrations were determined by two forms of tests:

1. Penetrance tests, in which the preservative was applied to a small area in the specimen and measurements made of the penetrations secured.[1]

2. Impregnation tests, in which the specimens were treated with the preservative under pressure in a cylinder.

The bulletin describes (a) tests made with mixtures of coal-tar creosote and coal tar from which the free carbon had been removed and similar mixtures containing varying amounts of free carbon; and (b) tests made with commercial coal-tar creosotes. The object in both cases was to determine the effect on penetration of differences in the preservative.

The bulletin also gives the results obtained in experiments to determine the effect of varying pressure, time of treatment, and temperature. The object of these experiments was to determine whether, by increasing the time of treatment, intensity of pressure, and temperature of preservative, absorptions and penetrations could be obtained with tar and creosote mixtures equivalent to those obtained with creosote, and to determine which of these factors was the most important.

MATERIALS USED.

WOOD.

Selected air-dried heartwood of longleaf pine was employed in all of the experiments. The specimens used in the penetrance tests were approximately 2 inches by 4 inches in cross section and of varying lengths from 18 inches to 24 inches. Pieces cut from the same stick were regarded as matched and were designated as a set of specimens. Test pieces selected in this manner were more uniform in structure than unmatched material, and the variables introduced by differences in structure were thus reduced. From two to four sets of matched specimens were used in each series of tests, the results being averaged for each test. Where these results are represented graphically, each figure includes only tests with such matched speci-

[1] A description of the apparatus used (fig. 14) is given in the Appendix.

mens, and comparisons can not be made by combining data used in separate figures.

The number of specimens used in each test is shown in the tables in the appendix. Specimens for the cylinder treatments discussed on pages 6 and 9 were paving blocks 4 inches long cut from two sticks of air-dry commercial paving block stock approximately 4 inches by 8 inches in cross section. In each of the tests a treatment was made on one block from each stick, thus giving two blocks treated with the same preservative. Blocks used in the tests on the effect of varying time, pressure, and temperature were all cut from the same stick, the material being similar to that used in the impregnation tests. Four blocks were treated with each preservative. In all of the impregnation tests, the results for each treatment were averaged.

Comparisons of individual tests from different sets of specimens should not be made, because such comparisons would not represent matched specimens. Specimens in the different sets may have been obtained from different trees.

PRESERVATIVES.[1]

Six commercial coal-tar creosotes from different sources and of varying specific gravities and five coal tars from by-product ovens and gas-house plants were used in the experiments. The general characteristics of these preservatives were as follows:

Characteristics of preservatives used.

Coal-tar creosotes.			Coal tars.		
No.	Kind.	Specific gravity at 60°C.	No.	Kind.	Free carbon.
					Per cent.
1	Coal-tar creosote containing coal tar (estimated at about 10 per cent).	1.0483	1	By-product coke-oven tar	6.0
2	Coal-tar creosote	1.0475	2	By-product coke-oven tar	16.0
3	Coal-tar creosote	1.0576	3	Gas-house coal tar	30.0
4	Coal-tar creosote containing coal tar (estimated at less than 5 per cent).	1.0710	4	By-product coke oven-refined tar.	7.0
5	High boiling coal-tar creosote	1.1050	5	By-product coke-oven tar	14.0
6	Coal-tar creosote	1.0470			

PREPARATION OF MIXTURES FOR THE TESTS ON THE EFFECT OF DIFFERENCES IN THE PRESERVATIVE.

The free carbon was extracted [2] from tars Nos. 1, 2, and 3. Each of these tars was then mixed with creosote No. 4 in the following proportions (by volume at 160° F.):

[1] Analyses of the creosotes are given in the Appendix. Distillation analyses of the tars were not made.

[2] See appendix for method of extraction.

Per cent of total mixture by volume.

Creosote No. 4.	Tar.
100	0
75	25
50	50
25	75
0	100

In order to obtain data on the effect of free carbon on absorption and penetration, it was necessary to vary the amount of free carbon in each of the three tars. This was accomplished by combining the proper proportions of normal [1] tar with tar of the same origin from which the free carbon had been removed. These mixtures were made by weight. The tars containing the varying percentages of free carbon were then mixed with creosote by volume in the proportion of 50 per cent tar and 50 per cent creosote.

CHARACTER OF FREE CARBON.

The free carbon was extracted with the least difficulty from the tar containing the highest percentage of free carbon (tar No. 3) and with the most difficulty from the tar containing the lowest percentage of free carbon (tar No. 1). A greater number of filtrations were required with tar No. 1, and a mat of free carbon of given thickness was more inclined to be impervious to additional tar than in the case of the other tars. The carbon mat formed from the tar having the largest amount of free carbon appeared to be the most pervious.

Tars Nos. 1, 2, and 3 were examined under the microscope at a magnification of 400 diameters. Plates I to III, inclusive, are photomicrographs of thin films of mixtures of equal parts by volume of creosote and each of the three normal tars. It is evident that the free carbon agglomerations are largest in the tar containing the highest percentage of free carbon.

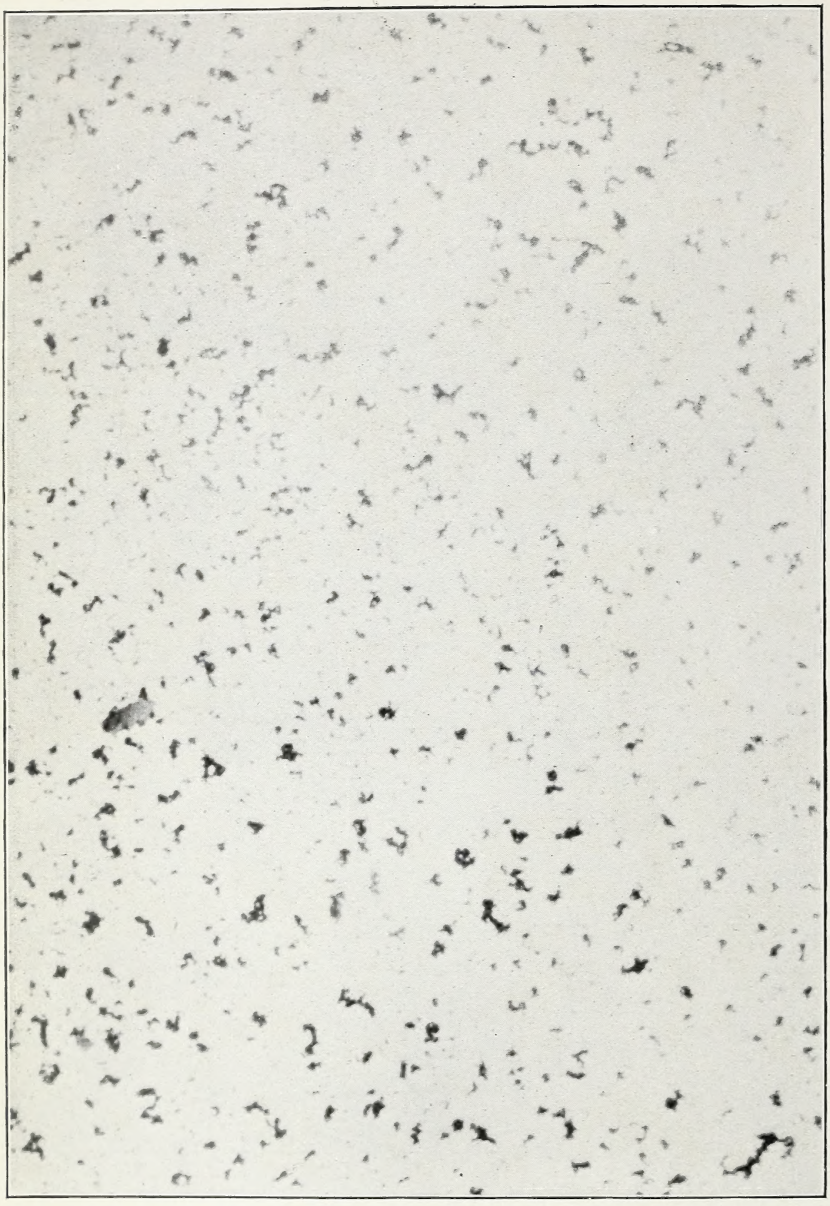
PRESERVATIVES USED FOR THE TESTS ON THE EFFECT OF VARYING TIME, PRESSURE, AND TEMPERATURE.

By-product coke-oven tars Nos. 1, 4, and 5, and coal-tar creosotes Nos. 4 and 6 were used in the experiments described on page 12. The proportion of tar and creosote in the mixtures and the temperatures, pressures, durations of treatment, and the results obtained are given in figures 18 to 27 and in tables 15 to 21 in the Appendix.

[1] By normal tar is meant tar containing its original free carbon.

A THIN FILM OF A MIXTURE OF EQUAL PARTS, BY VOLUME, OF CREOSOTE AND NORMAL BY-PRODUCT COKE-OVEN TAR NO. 1 (NORMAL AMOUNT OF FREE CARBON IN TAR, 6 PER CENT, BY WEIGHT).

Magnification, about 400 diameters.

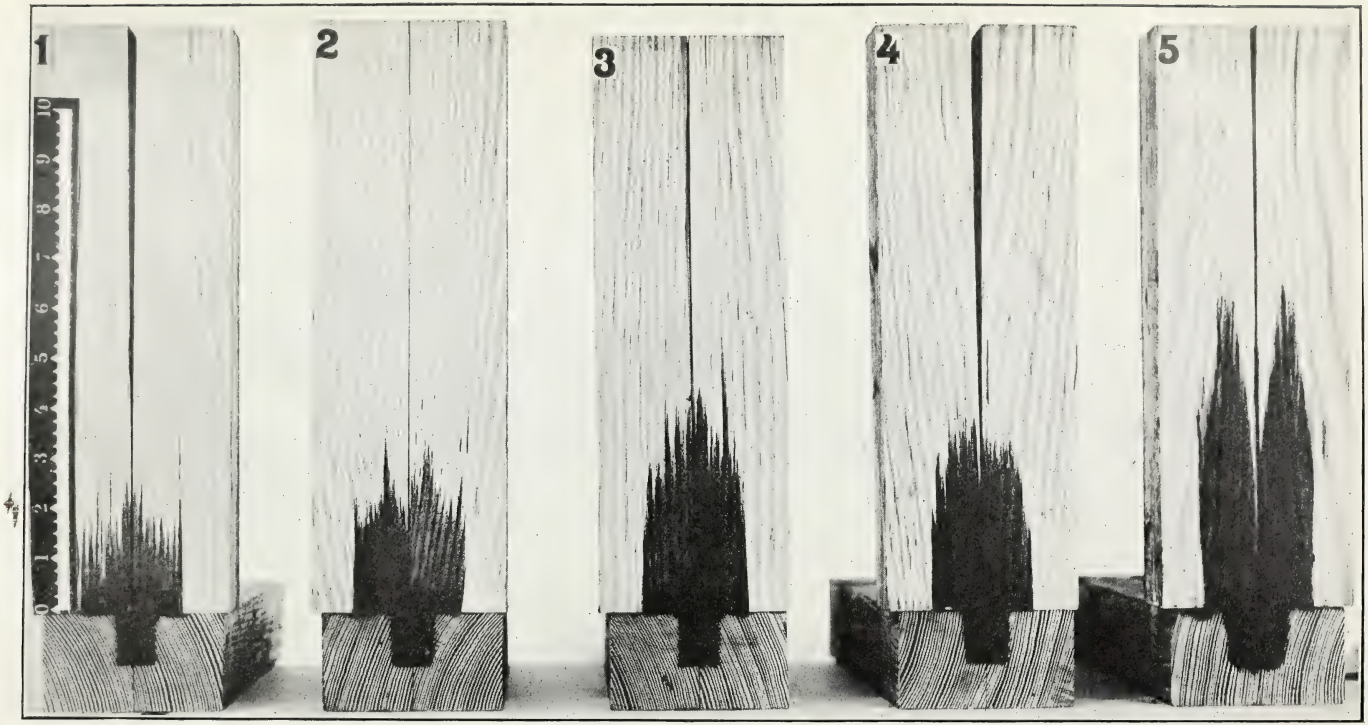


A THIN FILM OF A MIXTURE OF EQUAL PARTS, BY VOLUME, OF CREOSOTE AND NORMAL BY-PRODUCT COKE-OVEN TAR NO. 2 (NORMAL AMOUNT OF FREE CARBON IN TAR, 16 PER CENT, BY WEIGHT).

Magnification, about 400 diameters.

A THIN FILM OF A MIXTURE OF EQUAL PARTS, BY VOLUME, OF CREOSOTE AND A NORMAL GAS-HOUSE TAR NO. 3 (NORMAL AMOUNT OF FREE CARBON IN TAR, 30 PER CENT, BY WEIGHT).

Magnification, about 400 diameters.



MATCHED SPECIMENS OF LONGLEAF PINE TREATED WITH MIXTURES OF CREOSOTE NO. 4 AND A CARBON-FREE GAS-HOUSE TAR NO. 3 (NORMAL AMOUNT OF FREE CARBON IN TAR, 30 PER CENT, BY WEIGHT). (DATA IN TABLE 3, P. 29, AND TABLE A, P. 42.)

Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 160° F.

EFFECT ON PENETRATION OF DIFFERENCES IN THE PRESERVATIVE, ESPECIALLY THE EFFECT OF FREE CARBON.

Experiments with various mixtures of creosote and tars from which the free carbon had been removed were first made in the penetrance apparatus, the temperature, pressure, and time of treatment being kept constant. These tests were followed by cylinder treatments on paving blocks, with the same mixtures but with the time of treatment and the pressure varied to obtain an absorption of 16 pounds of preservative per cubic foot of wood. A similar series of penetrance and impregnation tests were made, using tar and creosote mixtures containing varying amounts of free carbon. Further tests were then made in the penetrance apparatus with five commercial coal-tar preservatives.

In the series of tests to determine the effect of differences in the preservative on penetration, the operative features were always the same A pressure of 75 pounds per square inch and a treating period of two hours were used. The temperature of the preservative and of the penetrance oven, in which the specimens were treated, was 160° F.

The treatments were made on two sets of specimens, each set containing from four to six matched specimens. Thus, each point on the curves of figure 4 represents the average of the results obtained on two specimens. The sets of specimens were not, however, matched with each other. For example (see Table 1, appendix), specimens 19a and 35 were not matched, but specimens 19a, 28, 32, 29, and 30, and specimen 35, 23a, 22a, 24a, and 20a were matched with each other.

MIXTURES OF CARBON-FREE TAR AND CREOSOTE.

Penetrance tests.[1]—(Tables 1 to 4, inclusive, and figs. 1 and 2.)

In these experiments, made with mixtures of tars Nos. 1, 2, and 3 with creosote No. 4, it is evident that as the proportion of the carbon-free tar in the mixture was increased the specific gravity and viscosity of the mixture increased and the absorptions and penetrations decreased. Each point on the absorption and penetration curves of figure 1 represents the results obtained with one tar and creosote mixture.

A comparison of these tars and their relative effect upon absorption and penetration is given in Table 4 and figure 2. These treatments were made with mixtures of equal parts by volume of creosote and each of the three carbon-free tars. Each point on the curves of figure 2 represents the average of the results obtained on two specimens, as in figure 1.

Figure 2 also shows the results obtained with similar mixtures of the same tar, except that the free carbon was not removed, and hence

[1] The data are given in Tables 1 to 4 of the Appendix.

gives a direct comparison for studying the effect of the free carbon on absorption and penetration.

The results of the tests indicate that smaller penetrations and absorptions were obtained with the mixtures of those tars which had contained the larger amounts of free carbon, whether the free carbon was present or had been removed. Variations in absorption and penetration of the different tar mixtures, therefore, appeared to be

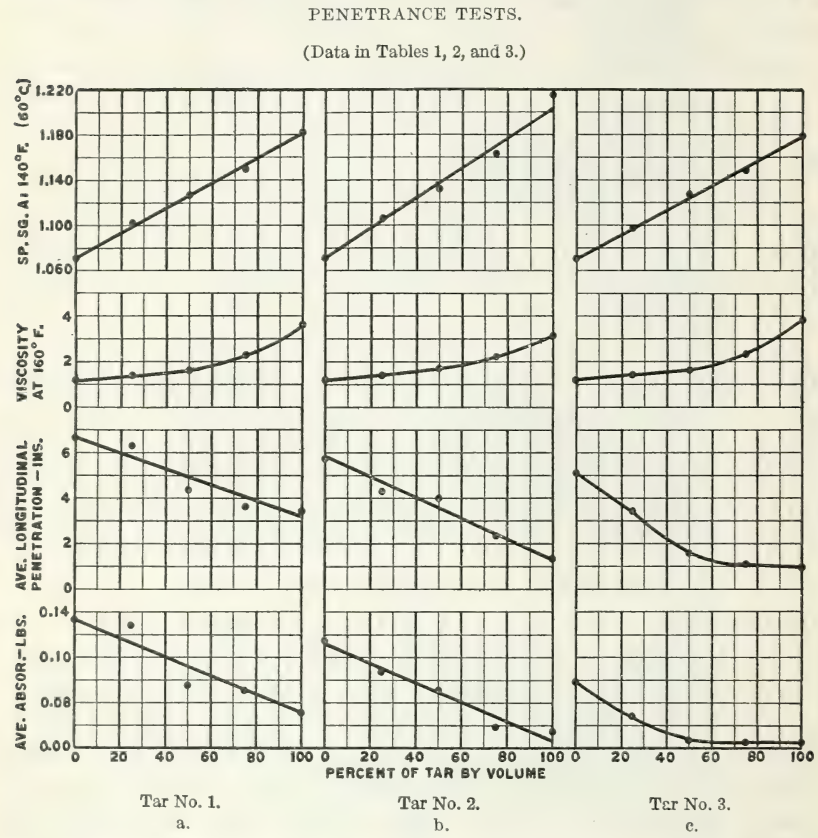


FIG. 1.—The relative absorptions and penetrations into longleaf pine of mixtures of creosote No. 4 and carbon-free tars Nos. 1, 2, and 3. Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature of preservative, 160° F.

caused by a difference in the composition of the bitumens in the three tars, as well as by the amount and character of the free carbon present.

Impregnation tests.—(Tables 5 to 7 and fig. 3.)

The paving block specimens were treated in a small cast-iron cylinder, inclosed in the penetrance oven, and with air pressure and vacuum connections. Two blocks were employed for each test, and the results averaged for each piont on the curves shown in figure 3.

Inasmuch as there were two variables in these tests, namely, time of treatment and the pressure, it was necessary to consider both of these factors; hence, the product of pressure and time has been used in the data presented. The tests were made at a higher temperature and pressure than were the penetrance tests but the mixtures were the same. In making the tests the temperature was kept constant.

The addition of tar made necessary the use of increased pressure or time of treatment or both to obtain the same absorption of preservative as was obtained with creosote.

After the tests, the blocks were split to determine the penetration and in most cases they were found to be fairly well penetrated when given an absorption of 16 pounds per cubic foot. However, a tendency to variation in penetration was greater in the blocks treated with the heavier and more viscous tar mixtures. Unpenetrated areas were found near the centers of some of the blocks which had been treated with preservatives containing 75 per cent and 100 per cent of tar.

MIXTURES OF CREOSOTE AND TAR WITH VARYING AMOUNTS OF FREE CARBON.

Penetrance tests.—(Tables 4, 8, 9, and 10 and figs. 2 and 4.)

The curves shown in figure 4 indicate that the influence of free carbon on penetration and absorption was greatest in the mixture made from tar No. 1, which contained normally 6 per cent of free carbon.

The curves also indicate that with an increase in the percentage

PENETRANCE TESTS.

(Data in Table 4.)

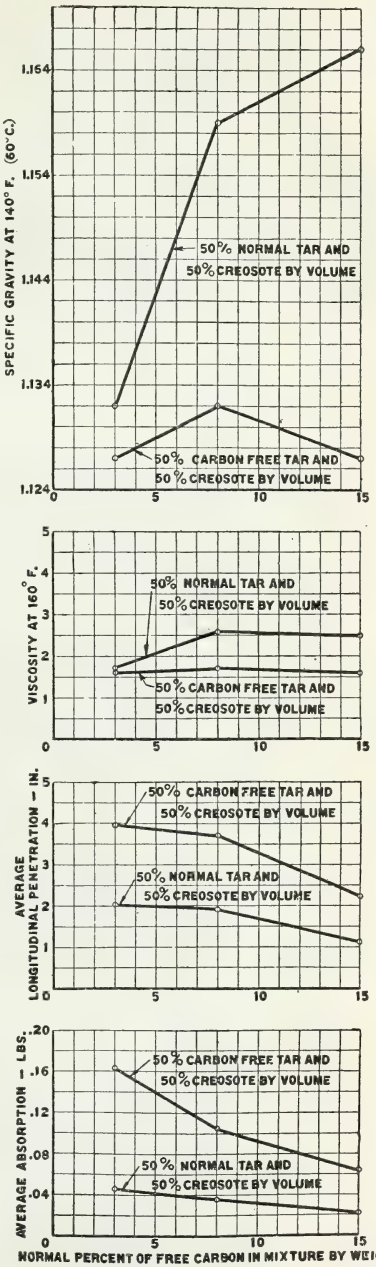

SPECIFIC GRAVITY AT 140° F. (60° C.)
1.164
1.154
1.144
1.134
1.124
50% NORMAL TAR AND 50% CREOSOTE BY VOLUME
50% CARBON FREE TAR AND 50% CREOSOTE BY VOLUME
0
5
10
15
VISCOSITY AT 160° F.
50% NORMAL TAR AND 50% CREOSOTE BY VOLUME
50% CARBON FREE TAR AND 50% CREOSOTE BY VOLUME
AVERAGE LONGITUDINAL PENETRATION — IN.
50% CARBON FREE TAR AND 50% CREOSOTE BY VOLUME
50% NORMAL TAR AND 50% CREOSOTE BY VOLUME
AVERAGE ABSORPTION — LBS.
.20
.16
.12
.08
.04
50% CARBON FREE TAR AND 50% CREOSOTE BY VOLUME
50% NORMAL TAR AND 50% CREOSOTE BY VOLUME
NORMAL PERCENT OF FREE CARBON IN MIXTURE BY WEIGHT

FIG. 2.—The relative absorptions and penetrations into longleaf pine of mixtures of equal proportions of creosote (No. 4) and three different tars (Nos. 1, 2, and 3). Two mixtures were made of each tar. The free carbon was removed from the tar in one mixture and the other contained the normal amount of free carbon. Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature of preservative, 160° F.

of free carbon in the mixture there was a decrease in the absorption and penetration. However, in the case of mixtures with tar No. 3 (fig. 4, *c*) after a certain point was reached there was a rise in the penetration and absorption curves upon the addition of larger per-

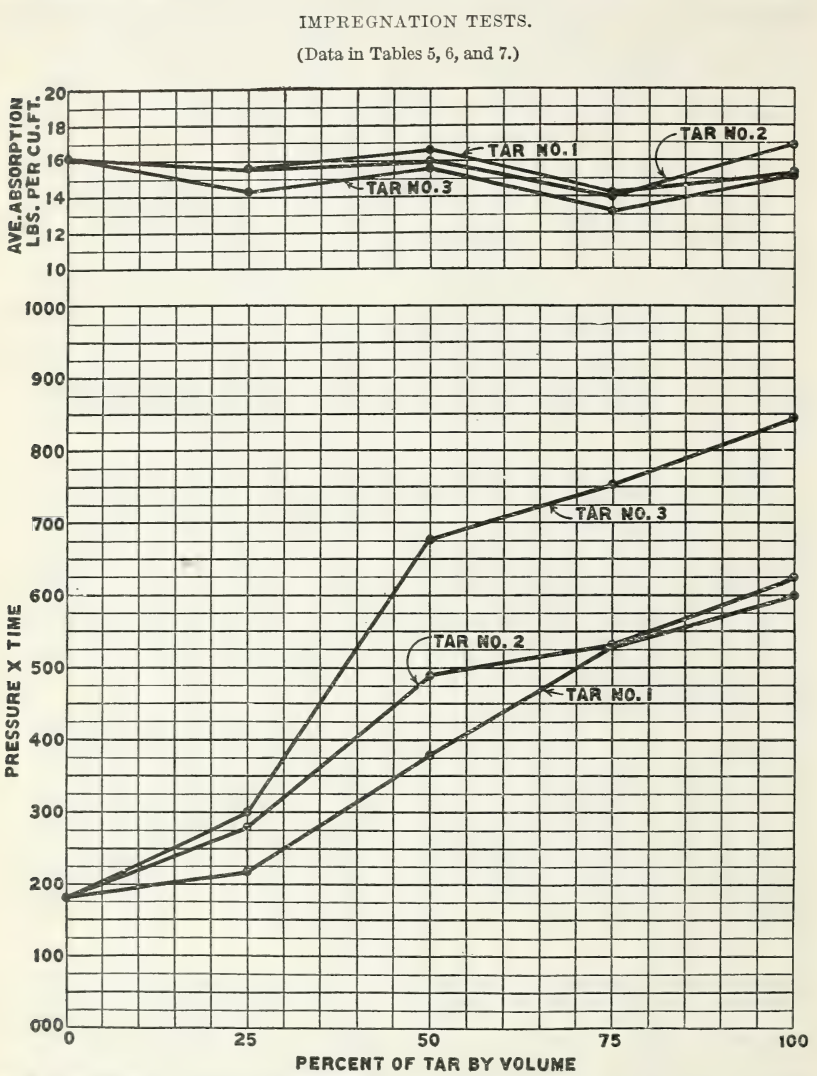
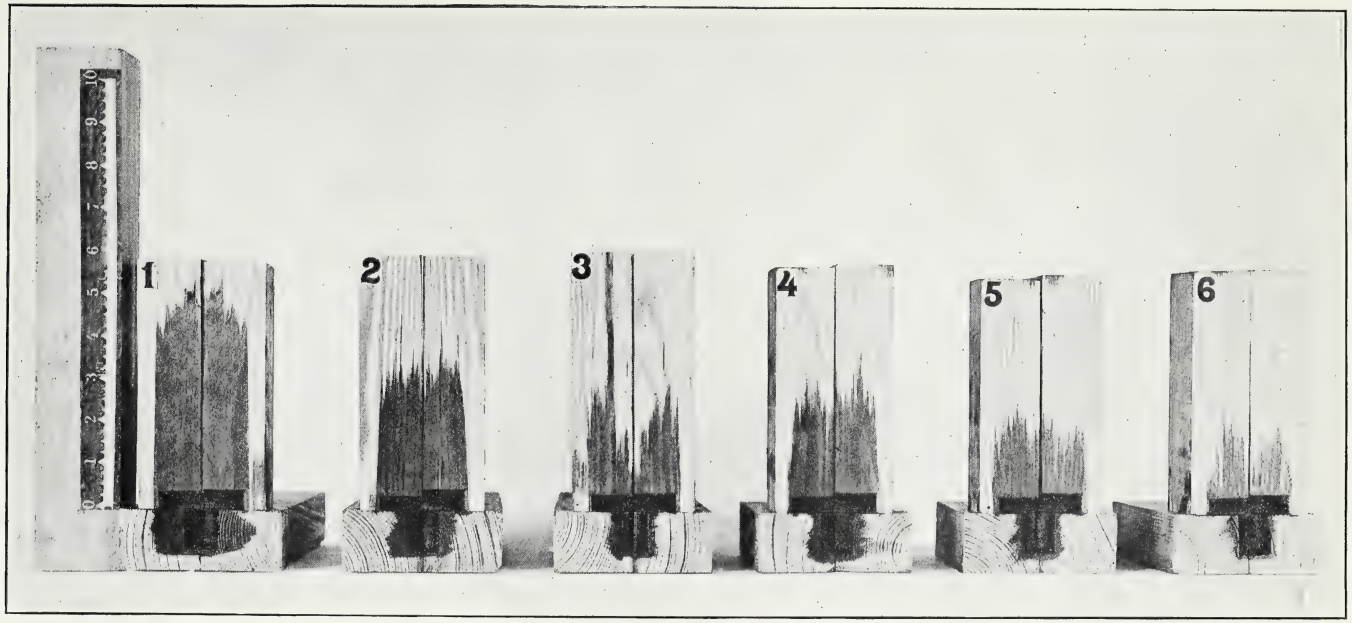


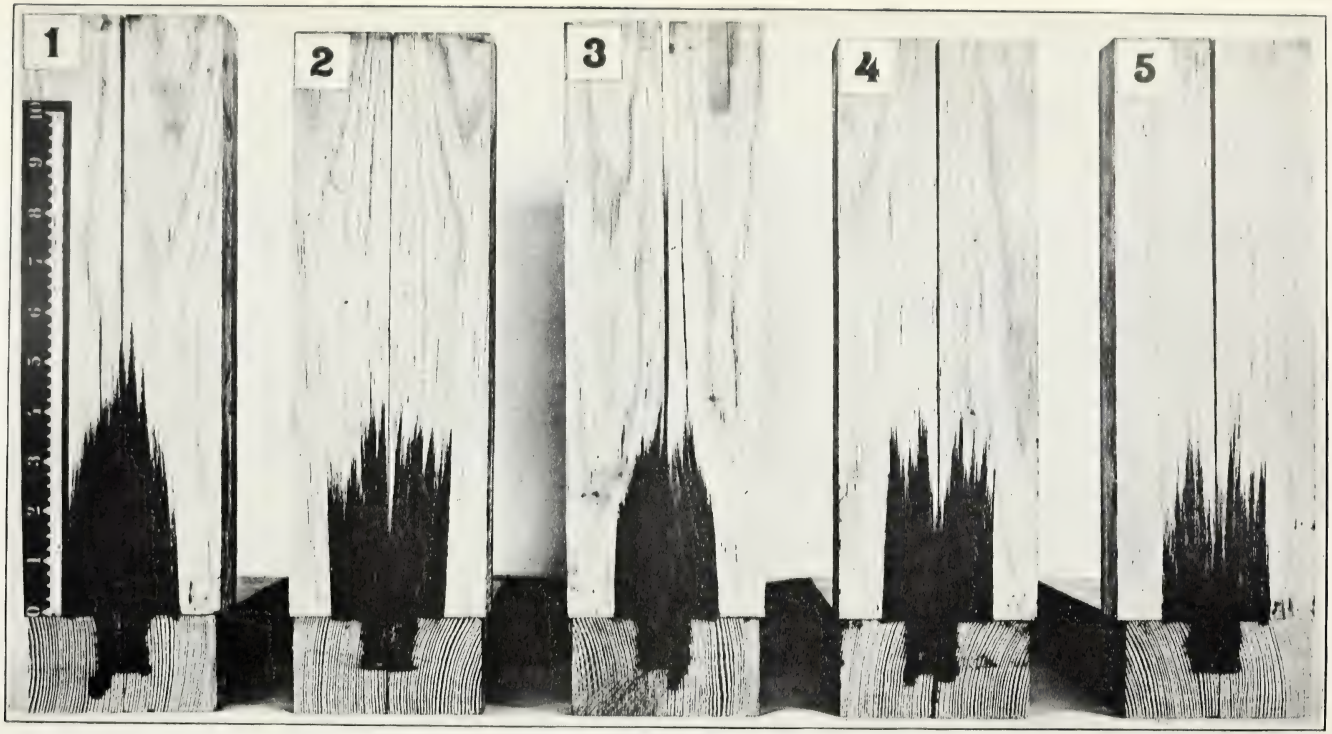
FIG. 3.—The variation in time of treatment and pressure necessary to secure a given absorption in paving blocks using mixtures of creosote No. 4 and carbon-free tars Nos. 1, 2, and 3.

centages of free carbon to the mixture. It is probable that this was caused by the character of the free carbon mats formed on the surface of the wood as the mixture was forced into the interior of the specimens. The free carbon particles in tar No. 3 were very much



MATCHED SPECIMENS OF LONGLEAF PINE TREATED WITH MIXTURES OF EQUAL PROPORTIONS OF CREOSOTE NO. 4 AND THREE DIFFERENT CARBON-FREE AND NORMAL-FREE CARBON TARS, NOS. 1 TO 3. (DATA IN TABLE 4, P. 30, AND TABLE B, P. 42.)

Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 160° F.



MATCHED SPECIMENS OF LONGLEAF PINE TREATED WITH MIXTURES OF EQUAL PARTS OF CREOSOTE NO. 4 AND A BY-PRODUCT COKE-OVEN TAR NO. 2 CONTAINING DIFFERENT AMOUNTS OF FREE CARBON (NORMAL AMOUNT OF FREE CARBON IN TAR, 16 PER CENT, BY WEIGHT). (DATA IN TABLE 9, P. 33, AND TABLE C, P. 42.)

Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 160° F.

larger than those in tars 1 and 2, and formed a less impervious mat. It seems probable that the mat formed with this tar containing its normal amount of free carbon contained openings as large and as easily penetrated as those formed when part of the carbon was removed.

PENETRANCE TESTS.

(Data in Tables 8, 9, and 10.)

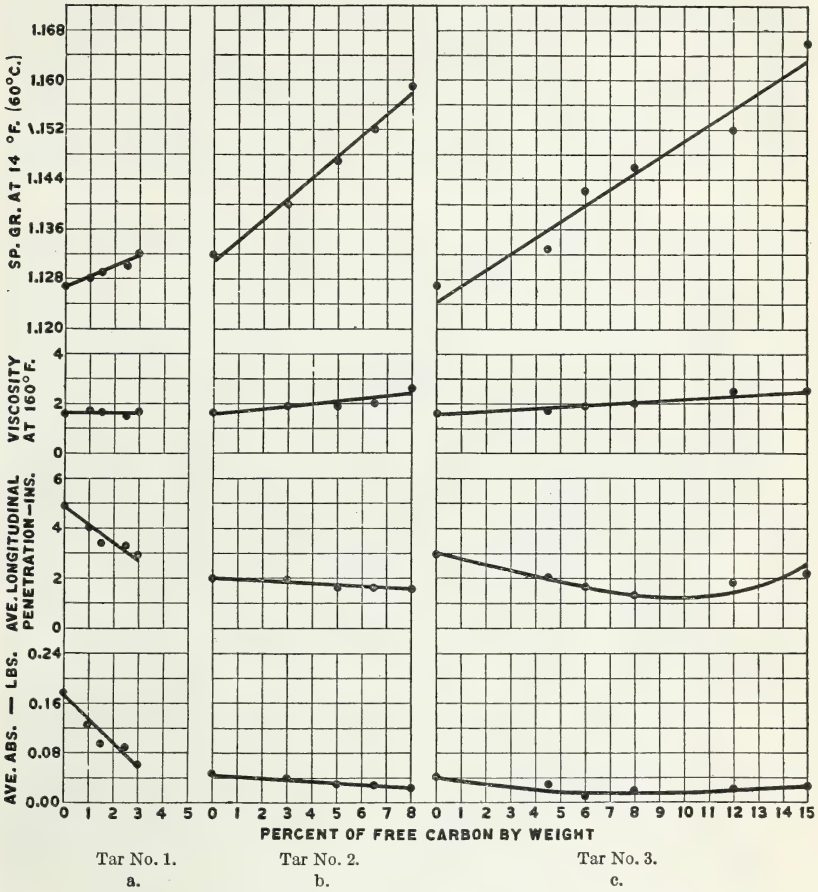


FIG. 4.—The relative absorptions and penetrations into longleaf pine using mixtures of equal parts of creosote No. 4 and tars containing different amounts of free carbon. Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature of preservative, 160° F.

Impregnation tests.—(Tables 11 to 13 and fig. 5).

Impregnation tests were made on paving blocks, using the same mixtures, with varying amounts of free carbon, that were used in the penetrance tests.

As in the impregnation treatments with carbon-free tar and creosote, two blocks were used for each test, and the time of treatment and

pressure were varied so as to obtain approximately 16 pounds absorption per cubic foot.

Figure 5 indicates that when the amount of free carbon in the mixtures was increased, the difficulty of securing a given absorption

IMPREGNATION TESTS.

(Data in Tables 11, 12, and 13.)

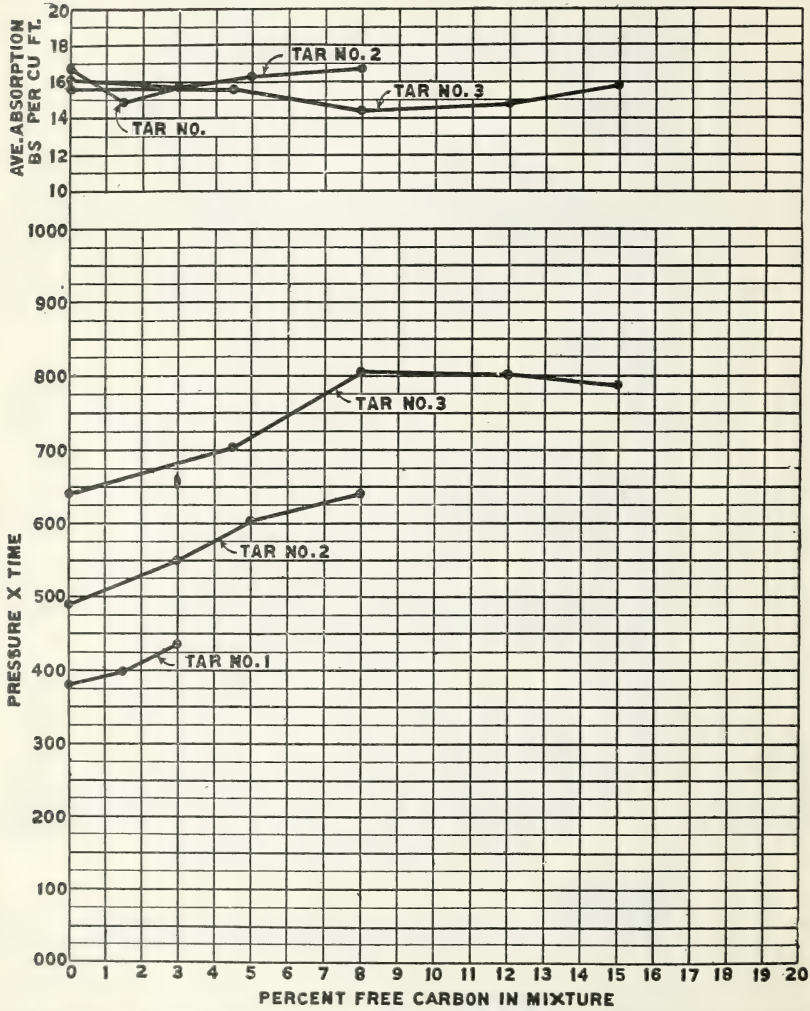


FIG. 5.—Variation in time of treatment and pressure necessary to secure a given absorption in paving blocks using mixtures of equal parts creosote No. 4 and tars having different amounts of free carbon.

was increased. As in the penetrance tests, however, the effect of free carbon was variable in the mixtures containing tar No. 3. The retarding effect of free carbon apparently decreased when the amount in the mixtures was increased beyond a certain point. This was

probably due, as noted in the case of the penetrance tests, to the character of the carbon mat which formed when this tar was used.

Blocks treated with the mixtures containing varying amounts of free carbon were found to be fairly well penetrated. By using a sufficient treating period and pressure, and a temperature of 200° F., it was possible to obtain 16 pounds absorption per cubic foot in all of the treatments on paving blocks.

The experiments taken in conjunction with the penetrance tests, indicate that three factors influenced absorption and penetration, namely, (1) the composition or per cent of bitumens contained in the tar, (2) the amount of free carbon contained in the mixture, and (3) the condition of the carbon or size of the free carbon agglomerations.

INFLUENCE OF COMPOSITION OF THE TARS.

The influence of the composition or per cent of bitumens contained in the tar is shown by the fact that the addition of high-carbon tars to creosote retarded penetration more than similar additions of low-carbon tars, even though the carbon had been removed. The amount of carbon in tar depends to a considerable extent upon the temperature at which it is produced, the higher temperatures producing tars with greater carbon content. It is concluded that tars produced at high temperatures may have a greater effect in retarding penetration than those produced at lower temperatures, whether or not the carbon is removed. Experience has shown that tars having a high carbon content also usually have a high bitumen content.

The condition of the free carbon apparently had a greater influence on absorption and penetration than the amount contained in the mixture. Since the free-carbon agglomerations were largest in the tar containing the highest percentage of free carbon (tar No. 3), this probably accounts for the relatively slight retarding influence of the free carbon in this tar, on absorption and penetration. In the mixtures containing smaller amounts of free carbon, the free carbon particles would come in closer contact with the vessels in the wood, thereby decreasing the absorption and penetration.

PENETRATION OF FREE CARBON INTO WOOD.

In order to determine whether any of the free carbon had penetrated the wood, sections were taken of specimens of heart longleaf pine treated with mixtures of equal parts of creosote and tars Nos. 1, 2, and 3, containing the normal amounts of free carbon. These sections were taken just below the surface through which the preservative entered. A microscopic examination was made at a magnification of 400 diameters but no free carbon could be observed in the wood cells. Some of the preservative was squeezed out of the wood sections in small globules and examined under the microscope. In this case

no free carbon could be detected at the magnification used. The sections were further treated with chloroform and xylol separately to remove the treating oils. Examination with the microscope, of these resulting solutions, also failed to show the presence of free carbon.

Dr. Irving W. Bailey [1] has shown that extremely finely divided carbon particles in certain India inks will penetrate wood, but such carbon particles can not be compared with the much larger ones occurring in coal tars.

TESTS WITH MISCELLANEOUS COMMERCIAL CREOSOTES.

Penetrance tests.—(Table 14 and fig. 6.)

Creosotes Nos. 1 to 5 were used in experiments to determine the penetrations and absorptions of miscellaneous commercial creosotes, the specific gravities varied from 1.0475 to 1.105 at 60° C., thus covering a wide range of oils. The method of treatment was the same for each oil. Creosotes Nos. 1 and 4 contained some tar, while creosotes 2 and 3 were free from tar. Figure 6 shows how the tar tended to retard the penetration. It will also be noted that creosotes Nos. 1 and 5, both oils being free from tar, had similar absorptions and penetrations, although the specific gravity of No. 1 was 1.05 while No. 5 was 1.12. This shows the wide variation that can exist in the specific gravity of oils free from tar, with but little difference in the penetrating properties.

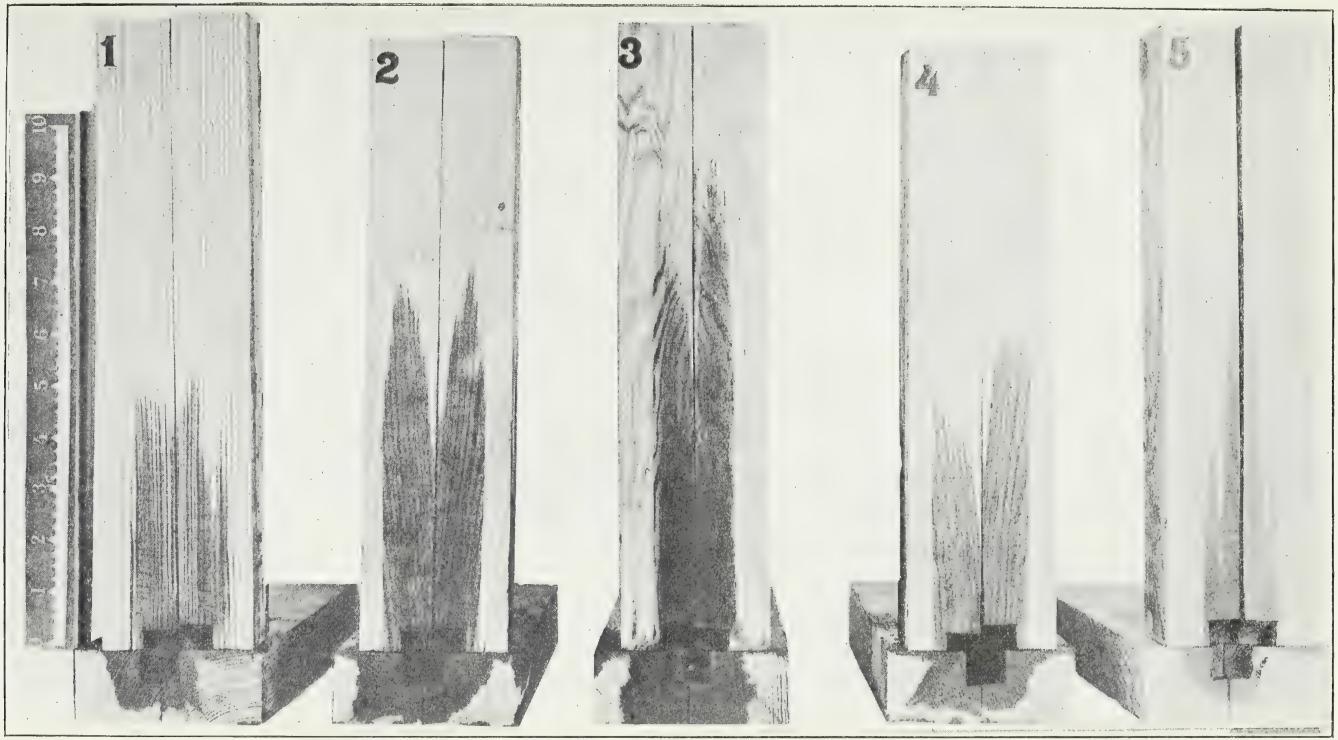
INFLUENCE OF VISCOSITY.

The viscosities of mixtures of a given tar and creosote in general increased (1) as the per cent of tar was increased, (2) as the per cent of free carbon was increased, (3) or as the temperature was lowered and in these mixtures the absorptions and penetrations generally decreased as the viscosity increased. When different tars were used in the mixtures, there did not appear to be a definite relation between viscosity and the absorptions or penetrations obtained. Thus in figure 2, the viscosities of the three mixtures of carbon-free tars and creosotes were about the same, although both penetrations and absorptions vary greatly. A comparison of the viscosities of the creosote-tar mixtures in Tables 4, 5, and 6, also indicates no apparent relation to the absorptions and penetrations when different tars are used.

TESTS OF THE EFFECT OF VARYING TIME, PRESSURE, AND TEMPERATURE.

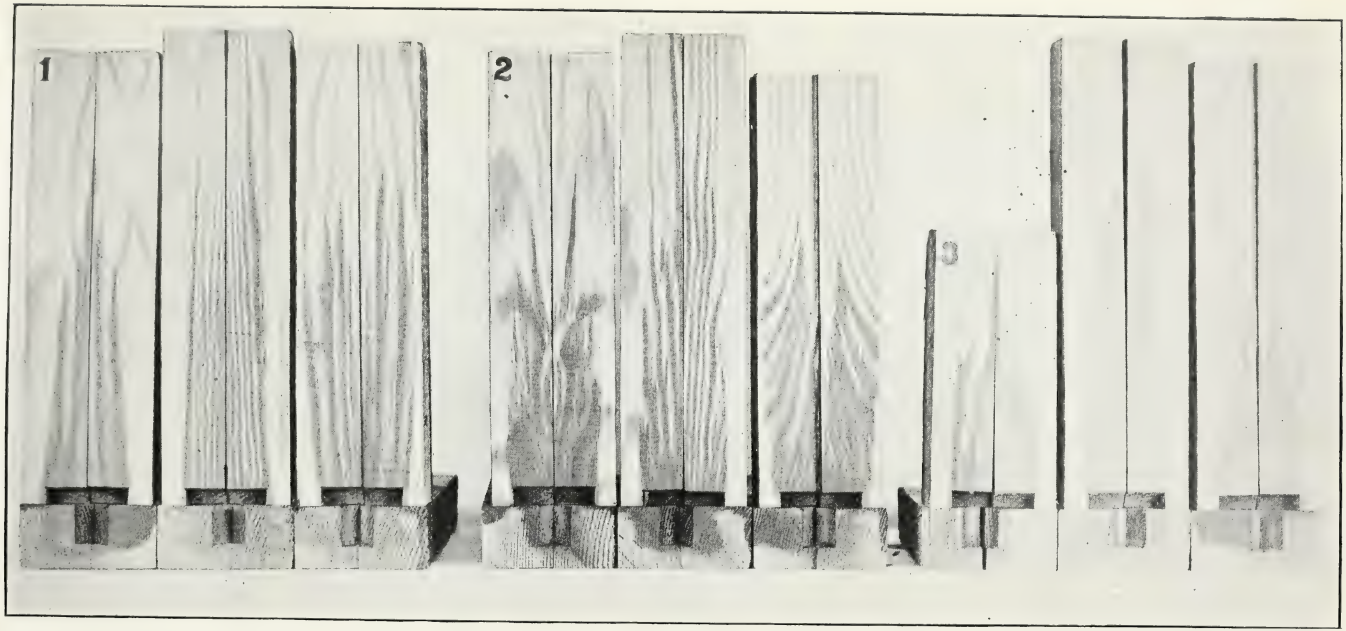
The results of the experiments described on page 7 indicate that in general the absorption and penetration of a tar and creosote mixture decreases as the amount of tar or free carbon in the mixture is

[1] Forestry Quarterly, March, 1913.



MATCHED SPECIMENS OF LONGLEAF PINE TREATED WITH VARIOUS COMMERCIAL CREOSOTES. (DATA IN TABLE 14, P. 36, AND TABLE D, P. 42.)

Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 160° F.



PENETRANCE SPECIMENS.

Group No. 1 treated with creosote. Group No. 2 treated with 80 per cent creosote, 20 per cent tar. Group No. 3 treated with 66⅔ per cent creosote, 33⅓ per cent tar. Specimens arranged in order of treatment as given in Table 15. Time of treatment, 2 hours; pressure, 80 pounds per square inch; temperature, 180° F.

increased, the conditions of treatment being constant. Experiments were made to determine the effect on the absorptions and penetrations of tar and creosote mixtures of an increase in the time of treatment, the intensity of the pressure, or the temperature of the pre-

PENETRANCE TESTS.

(Data in Table 14.)

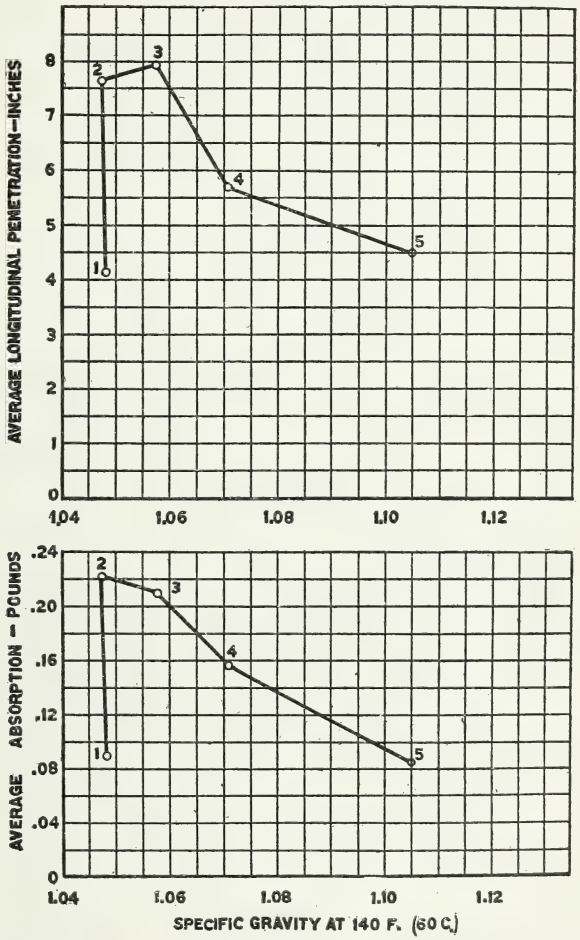


FIG. 6.—The relative absorptions and penetrations into longleaf pine of various commercial creosotes.

Point No.	Creosote No.	Kind of creosote.
1	1	Creosote containing tar (estimated at about 10 per cent).
2	2	Creosote.
3	3	Pure coal-tar creosote.
4	4	Creosote containing tar (estimated at less than 5 per cent).
5	5	High-boiling creosote.

Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 160° F.

servative. Two series of tests were made with the temperature and pressure of the preservative constant and the time of treatment varied to obtain the same absorption with the mixture as was obtained with the creosote unmixed with tar. Another series of tests was run, in which the pressure of the preservative was varied but the temperature and the time of treatment kept constant, and a comparison made of the pressures required to obtain the same absorption with various tar mixtures as was obtained with creosote unmixed with tar. A further series of tests was made in which the time of treatment, pressure of the preservative, and absorption were constant, but the temperature was varied. For comparison a test was made of the absorptions and penetrations obtained using the same time of treatment, temperature, and pressure of preservative for both the creosote unmixed with tar and for the tar mixtures.

The system of matching the penetrance specimens used in the experiments described on pages 4 to 20 was the same as that described on page 2, except that in one test four specimens were used and in other tests three specimens were used instead of two, as in the previous experiments. All of the blocks used in the impregnation tests were cut from the same stick and are, therefore, considered matched with each other.

PENETRANCE TESTS WITH COAL-TAR CREOSOTE NO. 6 AND BY-PRODUCT COKE-OVEN TAR NO. 4.

Time of treatment, temperature of preservative, and pressure constant.—(Table 15 and fig. 7.)

The first series of tests was made to study the relative absorptions and penetrations obtained with the creosote unmixed with tar; with mixtures of 80 per cent creosote and 20 per cent tar; and with 66⅔ per cent creosote and 33⅓ per cent tar. The pressure, the time of treatment, and the temperature of the preservative were the same for every preservative. These tests were made for comparison with those on the same mixtures where the pressure, time, etc., were varied. Details of the treatment are given in Table 15.

The average absorption and the average longitudinal penetration obtained with the 80 per cent creosote and 20 per cent tar mixture were each about 73 per cent of that obtained with the creosote. In the case of the 66⅔ per cent creosote and 33⅓ per cent tar mixture the absorption was about 66 per cent and the average longitudinal penetration about 69 per cent of that secured with creosote.

Temperature of preservative and pressure constant and the time of treatment varied.—(Tables 16 and 17 and fig. 8.)

With the mixture containing 20 per cent tar and 80 per cent creosote it was necessary to increase the treating period from two

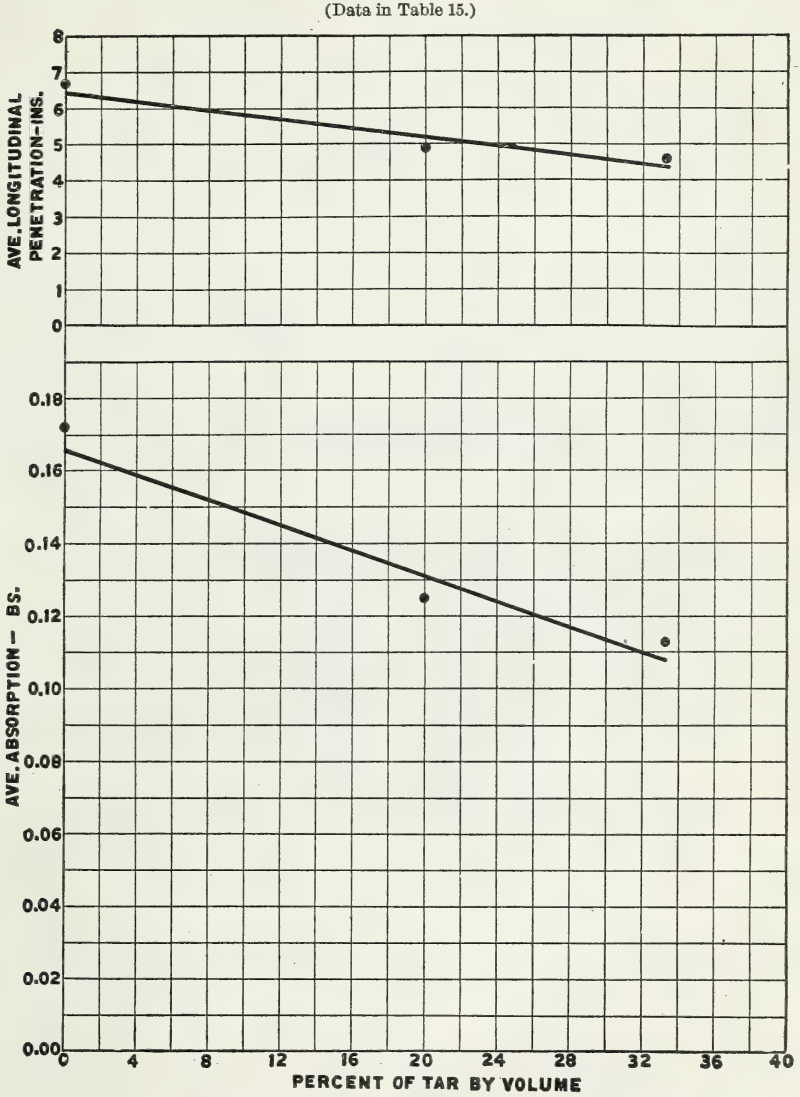


FIG. 7.—The relative absorptions and penetrations into longleaf pine using mixtures of creosote No. 6 and tar No. 4. Time of treatment, 2 hours; pressure, 80 pounds per square inch; temperature of preservative, 180° F.

hours to four hours to obtain the same absorption as when the creosote unmixed with tar was used. A reduction in the average

longitudinal penetration of about 17 per cent resulted from the increase in the proportion of tar.

When the mixture containing 33⅓ per cent of tar was used, it was noted that after the specimens had been treated for a certain length of time (see Table 15, footnote) no increase in the absorption was obtained. Hence it was not possible in this test (where the temperature of the preservative was 160° F. and the pressure 80 pounds per square inch) to obtain an absorption with the mixture equal to that obtained with the creosote, even when the time of treatment was increased to eight hours. The average longitudinal penetration was about 33 per cent less than obtained with the creosote.

PENETRANCE TESTS.

(Data in Tables 16 and 17.)

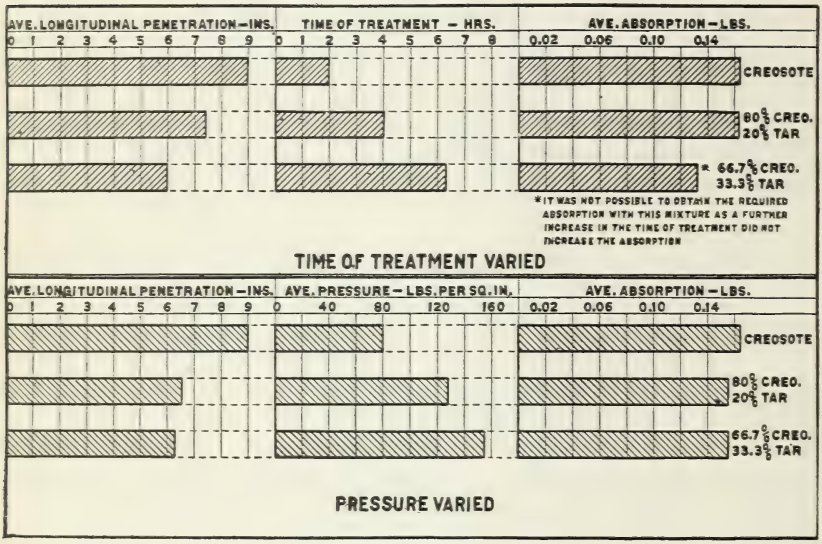
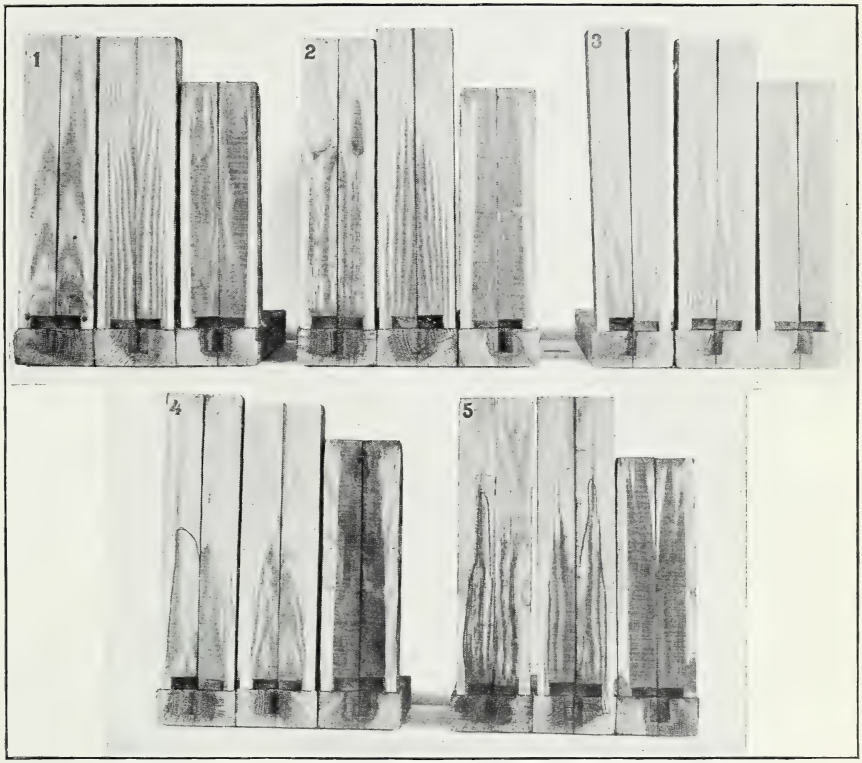

AVE. LONGITUDINAL PENETRATION—INS.
TIME OF TREATMENT — HRS.
AVE. ABSORPTION—LBS.
CREOSOTE
80% CREO. 20% TAR
* 66.7% CREO. 33.3% TAR
*IT WAS NOT POSSIBLE TO OBTAIN THE REQUIRED ABSORPTION WITH THIS MIXTURE AS A FURTHER INCREASE IN THE TIME OF TREATMENT DID NOT INCREASE THE ABSORPTION
TIME OF TREATMENT VARIED
AVE. LONGITUDINAL PENETRATION—INS.
AVE. PRESSURE—LBS. PER SQ. IN.
AVE. ABSORPTION—LBS.
CREOSOTE
80% CREO. 20% TAR
66.7% CREO. 33.3% TAR
PRESSURE VARIED

FIG. 8.—The relative effect of varying (1) time of treatment and (2) pressure in order to secure approximately the same absorption in longleaf pine using mixtures of tar No. 4 and creosote No. 6. With time varied the treating temperature was 160° F. and the pressure 80 pounds per square inch. With pressure varied the time of treatment was 2 hours and the temperature 160° F.

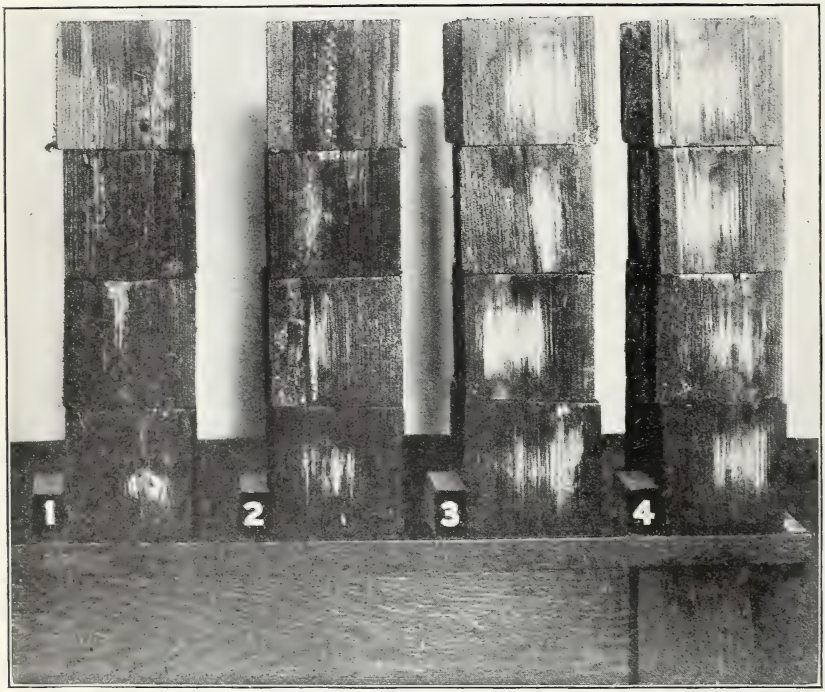
Time of treatment and temperature of preservative constant and pressure varied.—(Tables 16 and 17 and fig. 8.)

The specimens used in these tests were matched with those just preceding, and hence the results are directly comparable. The pressure required to obtain a given absorption in the test in which the temperature of the preservative and the time were constant was approximately proportional to the amount of the tar in the mixture. With almost the same absorption of preservative the penetrations of the two tar and creosote mixtures were from 27 to 29 per cent less than those obtained



PENETRANCE SPECIMENS.

Specimens arranged in order of treatment as given in Table 16. Group No. 1 treated with creosote. Time of treatment, 2 hours; pressure, 75 pounds per square inch; temperature, 180° F. Group No. 2 treated with 80 per cent creosote, 20 per cent tar. Time of treatment varied; temperature, 180° F. Group No. 3 treated with 66⅔ per cent creosote, 33⅓ per cent tar. Time of treatment varied; temperature, 180° F. Group No. 4 treated with 80 per cent creosote, 20 per cent tar. Pressure varied; temperature, 180° F. Group No. 5 treated with 66⅔ per cent creosote, 33⅓ per cent tar. Pressure varied; temperature, 180° F.



PENETRATION IN PAVING BLOCKS.

No. 1 blocks treated with creosote No. 4. No. 2 blocks treated with 75 per cent creosote No. 4 and 25 per cent tar No. 5. No. 3 blocks treated with 50 per cent creosote No. 4 and 50 per cent tar No. 5. No. 4 blocks treated with 25 per cent creosote No. 4 and 75 per cent tar No. 5.

with the creosote. Comparing these results with those in which the time of treatment was varied, it is noted that when the 20 per cent tar mixture was used better penetrations were obtained by lengthening the time of treatment than by increasing the pressure, the absorption being the same in both cases. This comparison can not properly be made with the mixture containing 33⅓ per cent tar, because the desired absorption was not obtained in this case when only the time of treatment was increased. (See note on fig. 8.)

IMPREGNATION TESTS.

(Data in Table 18.)

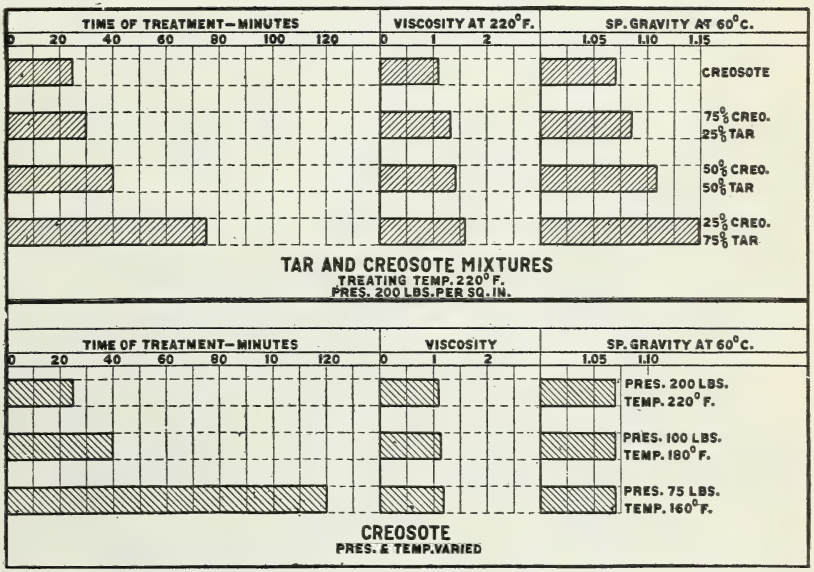


FIG. 9.—The time of treatment required to secure a given absorption in paving blocks using mixtures of creosote No. 4 and tar No. 5; also the increase in time of treatment required to secure a given absorption of creosote when the treating pressure and temperature were decreased.

IMPREGNATION TESTS WITH COAL-TAR CREOSOTE NO. 4 AND COAL-TAR NO. 5.

Temperature of preservative and pressure constant and time of treatment varied.—(Tables 19 and 20 and figs. 9 and 10.)

Tests to determine the effect of varying the time were made on matched paving-block specimens with mixtures containing 25 per cent tar and 75 per cent creosote, 50 per cent tar and 50 per cent creosote, and 75 per cent tar and 25 per cent creosote. Similar tests were made on penetrance specimens. (Fig. 10.) The creosote unmixed with tar was used for comparison. In these tests the time of treatment required to obtain a given absorption increased rapidly as the amount of tar in the mixture was increased, especially when 50 per cent and 75 per cent of tar were used. The desired absorption was obtained in the shortest time with creosote. In order to secure

approximately a corresponding absorption with the tar mixtures, the time of treatment was increased above that required for creosote by about 17 [1] per cent for the mixture containing 25 per cent tar, about 60 per cent for the mixture with 50 per cent tar, and 200 per cent for the mixture containing 75 per cent tar.

After treatment the blocks were split to determine the penetration. Those treated with creosote were completely penetrated, and those treated with the mixture containing 25 per cent tar were fairly well penetrated. A small area at the center of the blocks treated with mixtures having 50 and 75 per cent tar was unpenetrated. Plate X is a photograph of a set of these blocks when split.

PENETRANCE TESTS.

(Data in Table 19.)

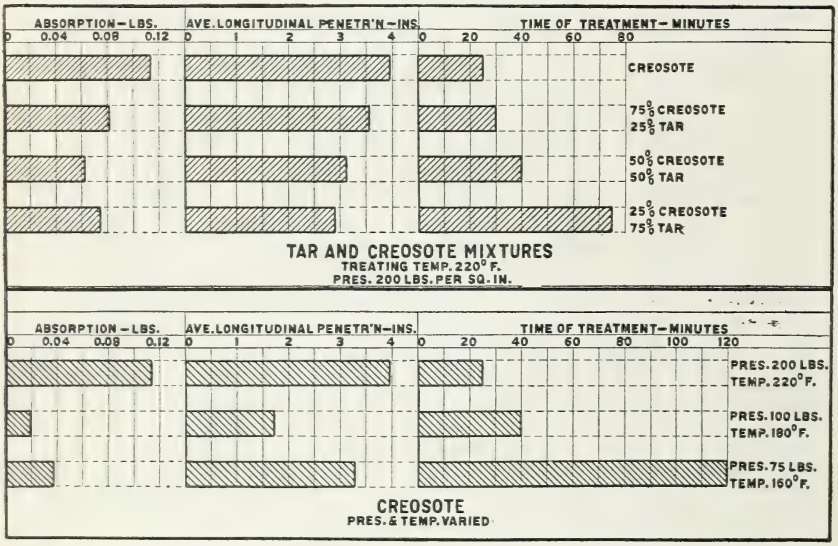


FIG. 10.—The relation between absorption, penetration, and time of treatment using mixtures of creosote No. 4 and tar No. 5; also the comparative effect of varying the pressure and time of treatment.

PENETRANCE TESTS WITH CREOSOTE NO. 4 AND TAR NOS. 1 AND 5.

Time of treatment and pressure constant and temperature varied.—(Tables 18 and 21 and figs. 11 and 12).

Two series of tests on the effect of varying the temperature were made, both on the penetrance apparatus. In the first series a mixture of 50 per cent creosote No. 4 and 50 per cent tar No. 1 was used. In the second, 75 per cent of tar No. 5 and 25 per cent of creosote No. 4 was used. Both the absorption and penetration were materially increased as the treating temperature was increased. The tests indicated that temperature is an important factor in absorption and

[1] Absorptions in these cases were about 9 per cent higher than with the creosote.

PENETRANCE TESTS.

(Data in Table 20.)

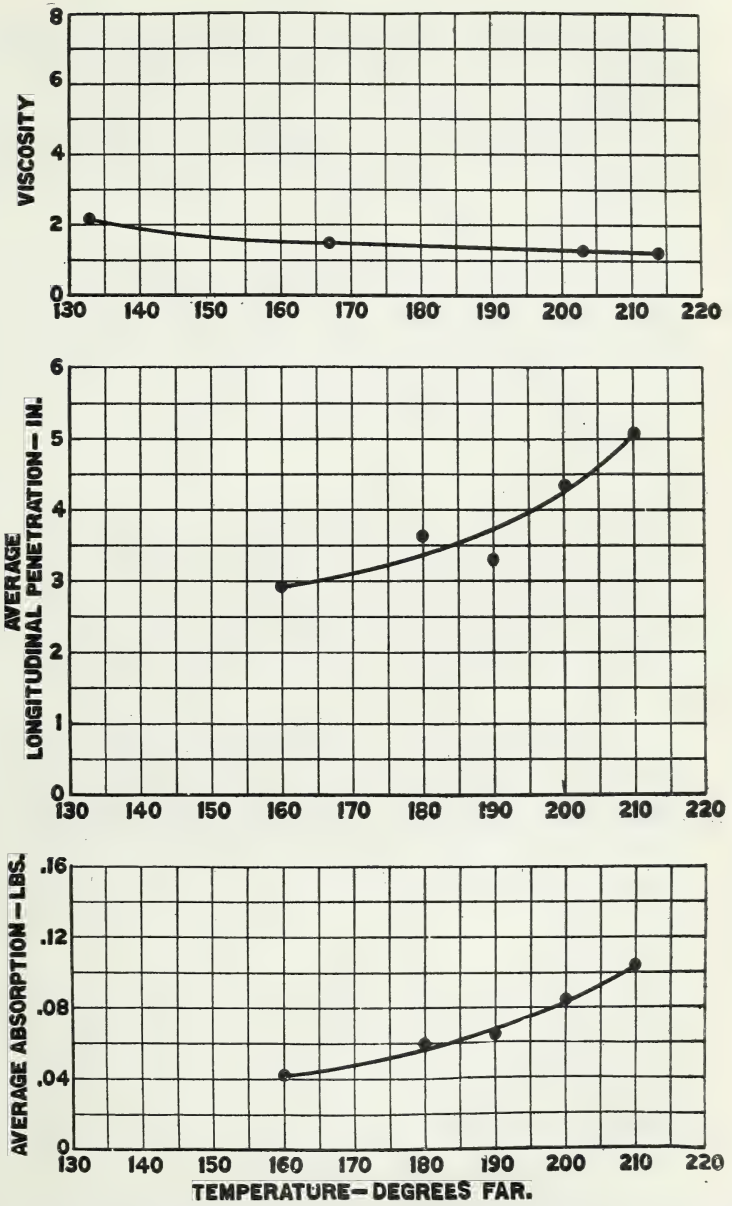


FIG. 11.—The relative absorptions and penetrations into longleaf pine of a mixture of equal parts of creosote No. 4 and a normal by-product coke-oven tar No. 1 at different temperatures (normal amount of free carbon in tar, 6 per cent, by weight). Time of treatment, 2 hours; pressure, 75 pounds per square inch.

penetration. Thus, in figure 11, the penetration at 210° F. was about two and one-half times that at 160° F., while the absorption

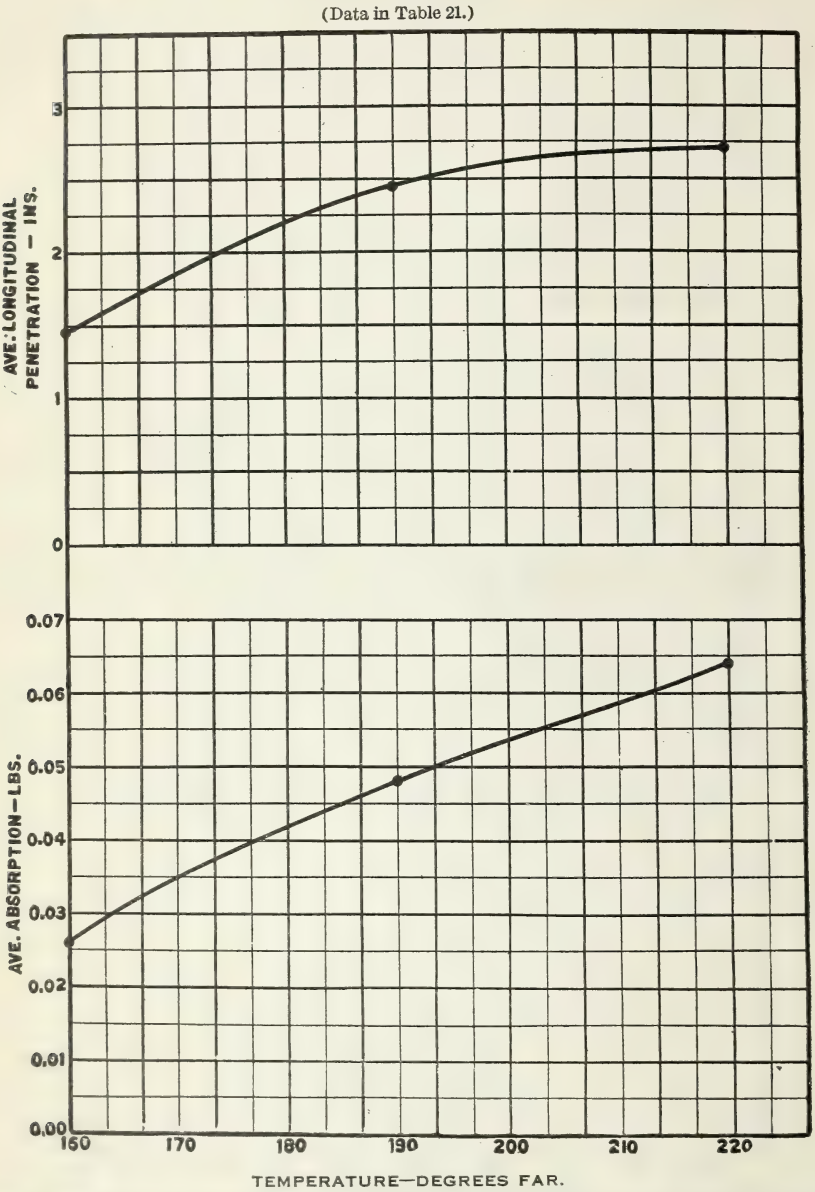
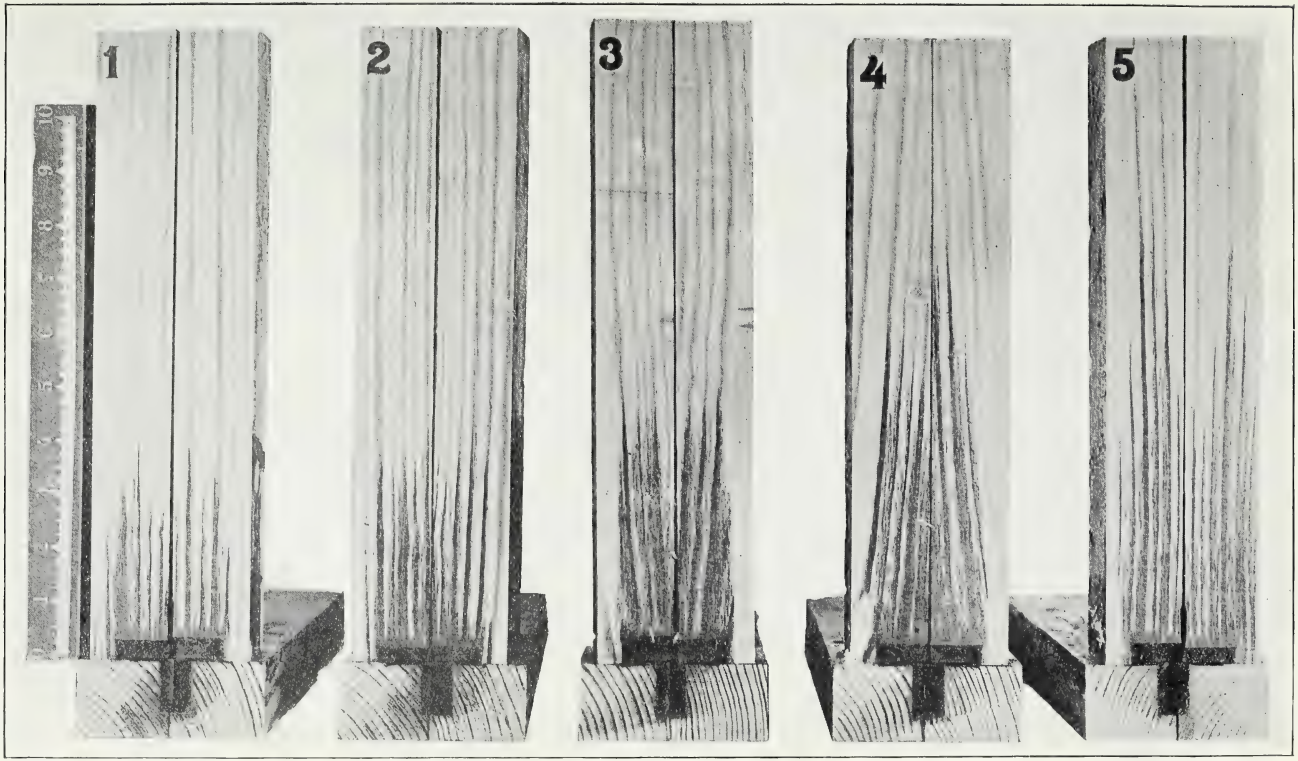


FIG. 12.—The relation between absorptions and penetrations into longleaf pine using a mixture of 25 per cent creosote No. 4 and 75 per cent tar No. 5 at different treating temperatures. Time of treatment, 1 hour; pressure, 200 pounds per square inch.

was 1.6 greater. In figure 12, with a mixture containing 75 per cent of tar, the penetration at 220° F. was also two and one-half times that at 160° F., while the absorption was twice as great.



Matched Specimens of Longleaf Pine Treated with a Mixture of Equal Parts of Creosote No. 4 and a Normal By-Product Coke-Oven Tar No. 1 at Different Temperatures (Normal Amount of Free Carbon in Tar, 6 Per Cent, by Weight). (Data in Table 20, p. 42, and Table E, p. 42.)

Time of treatment, 2 hours; pressure, 75 pounds per square inch.

SUMMARY.

The results of this investigation may be briefly summarized as follows:

The addition of coal tar to coal-tar creosote increased materially the difficulty of injection into heart longleaf pine. The resistance to impregnation was increased as the amount of tar was increased. Resistance to impregnation was greater to coal tars of high than to those of low free-carbon content. This was the case even when the free carbon was removed from these tars, indicating that the character of the bitumens as well as the free carbon influenced impregnation. The tests indicate that coal tars produced at relatively low temperatures penetrate better than those produced at relatively high temperatures. The size of the free-carbon particles was also found to be a factor in penetration, as those tars in which a large proportion of the particles were relatively small produced mats which were more nearly impervious to the passage of the preservative than those tars in which these particles were larger.

The relative viscosities of mixtures of coal tar creosote and coal tars from different sources are not necessarily a true index of their ability to penetrate wood. In these tests the viscosities of mixtures containing different tars did not appear to have any definite relation to the ease or difficulty of penetration.

For a mixture of a given tar and creosote the following three factors appear to be important in their relation to penetrations and absorptions:

1. The composition and character of the bitumens.
2. The amount of the free carbon in the tar.
3. The condition or size of the free carbon particles.

In the treatment of paving blocks the most general practice at present is to inject about 16 pounds of the preservative per cubic foot of wood. This absorption is not usually difficult to obtain in air-seasoned longleaf pine with coal tar creosote at relatively moderate pressures and temperatures, on account of the short length of the blocks (usually not over 4 inches). In these tests it was found that when coal tar was added to coal tar creosote, it was possible to obtain an absorption of 16 pounds per cubic foot by increasing the pressure, the temperature, and the time of treatment, the amount of the increase required depending upon the kind and amount of tar added. There was, however, a tendency to obtain less uniform penetrations with those mixtures containing the higher amounts of tar. Increasing the intensity of pressure was of greater importance in obtaining the desired absorption than increasing the time of treatment, while with a given absorption lengthening the time of treatment and using a

lower pressure gave better penetrations than shortening the time of treatment and increasing the pressure.

The temperature of the preservative was found to be very important. In the case of a mixture of tar and creosote containing 50 per cent of by-product coke-oven tar an increase in the temperature from 160° to 200° F. increased the absorption two and one-half times and penetration one and two-thirds times. A nearly similar result was obtained with another tar and creosote mixture containing 75 per cent of by-product coke-oven tar.

Since the tests were necessarily limited to a comparatively small number of tar and creosote mixtures and also to a small number of tests on each preservative, using only one species of wood, the relations brought out can not be considered as definitely established. The results may prove of value, however, in indicating some of the factors that bear an important relation to the injection of preservatives into wood.

In general, it might be expected from these results that if tar, either alone or in mixture with creosote, were used in the preservation of wood the difficulty of injection would increase as the percentage of tar and free carbon in the mixture was increased. The practice of filtering free carbon from tar and creosote mixtures, which is sometimes resorted to, would seem to offer a means of improving the penetrating properties of the preservative.

In these experiments those tars which contained normally the lower amounts of free carbon appeared to have better penetrating properties than those containing the higher amounts, even after the free carbon was removed. This suggests that mixtures containing low-carbon tars should prove easier to inject into the wood.

The results of the experiments in which the time of treatment, intensity of pressure, and temperature of the preservative were varied indicate that the pressure period should be as long as possible, the intensity of pressure being regulated to obtain the desired absorption, while the preservative should be at as high a temperature as it is practicable to work without injuring the wood. From 190° to 220° F. may be satisfactorily used in treating longleaf pine paving blocks.

The viscosity measurements made on the tar and creosote mixtures containing tar from different sources indicate that the viscosity may not always be a true index of the penetrating properties of the mixture and should probably not be relied upon for this purpose.

The quality of the wood used has a marked influence on the absorption and penetration. It has very frequently been observed that the springwood of rapid-growth southern pine is hard to penetrate. In general, better treatments may be obtained in wood which has narrow annual rings.

APPENDIX.

DETAILED DESCRIPTION OF TESTS.

Penetrance tests.—Each specimen before test was placed on a shelf in the oven of the penetrance apparatus and the temperature maintained at 160° F. for 24 hours.

A hole 1 inch in diameter and either ¾ or 1 inch deep was bored in the specimen. The piece was weighed to 0.001 of a pound immediately before and after treatment. The absorption of preservative by each specimen was determined from the difference in weights. About 24 hours after treatment each specimen was sawed longitudinally and transversely through the center of the hole on the lines indicated in figure 13. The treated areas shown on the surface thus exposed were measured by means of a planimeter and the average longitudinal penetrations determined from these measurements.

Impregnation tests.—The blocks were air-dried in the laboratory for several months; consequently they had a very small moisture content. Before treatment each block was weighed to 0.01 of a pound and the dimensions measured to 0.01 of an inch. The volume was

FIG. 13.—Appearance of test pieces.

determined from these measurements. After treatment each block was again weighed and the absorption in pounds per cubic foot computed.

APPARATUS.

The "penetrance apparatus," illustrated in figure 14, was designed for the penetrance tests. The wood under test, which had a 1-inch hole bored in it, figure 13, was clamped against the open end of the pipe A leading to the bottom of a pressure tank B. The pipe and lower portion of the tank were filled with the preservative. Pipe C, opening into the top of the tank, was connected with an air reservoir. When desired, air under pressure was turned into tank B, which thus placed the preservative under pressure. The apparatus was surrounded by a wooden oven R, with double glass windows in the front and back. Steam coils J in the bottom of the oven heated the specimens and preservatives to a uniform temperature, which duplicated as nearly as possible the temperature conditions of the treating cylinder. The pressure was determined from the gauge G and the temperature from thermometer H. A safety valve K aided in maintaining a uniform pressure. Shelves were provided and specimens were

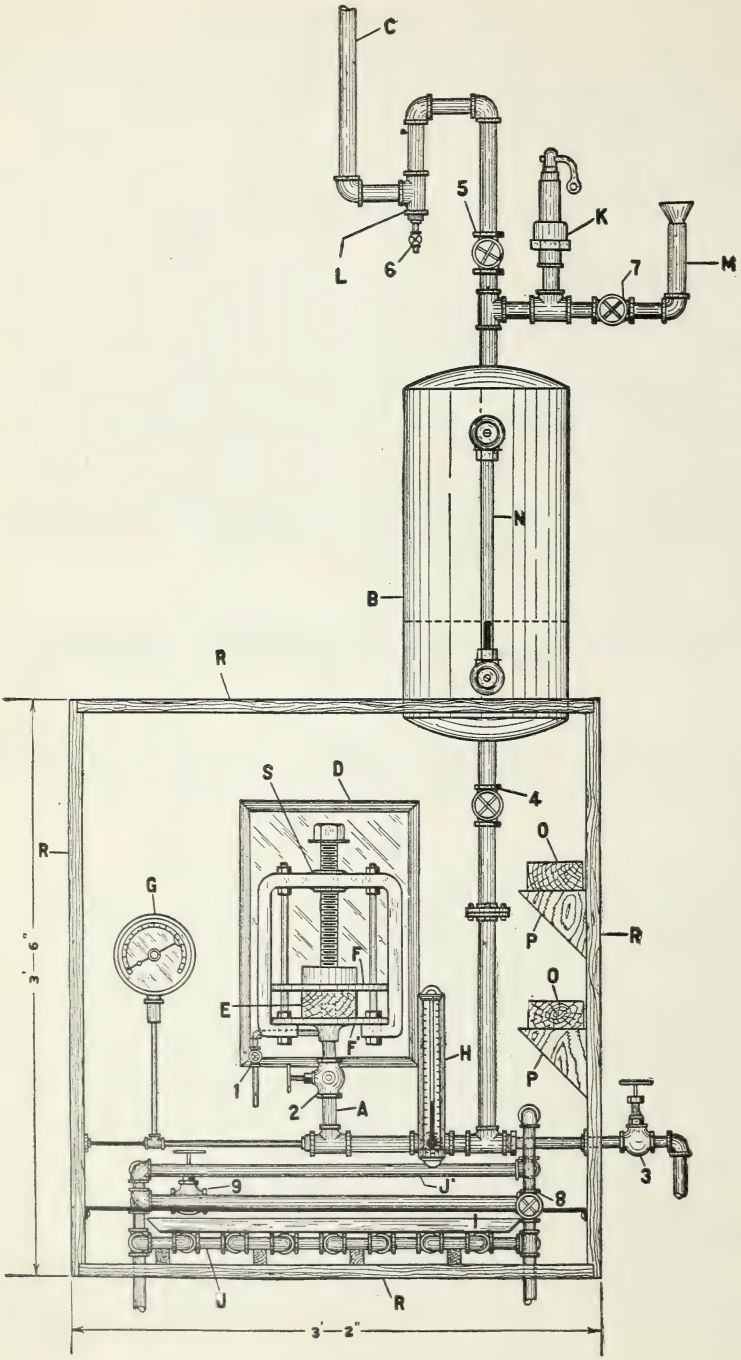


FIG. 14.—Apparatus for making penetrance tests.

placed in the apparatus previous to testing in order to heat them uniformly to the required temperature. By the aid of mirror D, placed at the back of the oven, both ends of the specimens were made visible.

In making the impregnation treatments on the paving-block specimens, small treating cylinders were used. The tests of the effect on penetration of differences in the preservative were made in a cylinder 6 inches in diameter and 12 inches deep which was substituted for the clamping device in the penetrance apparatus. Other impregnation tests were made in a 1½-foot by 4-foot treating cylinder.

METHOD OF OBTAINING CARBON-FREE TAR.

The free carbon was removed from a portion of tars Nos. 1, 2, and 3, as follows:

The tar was first dissolved in chloroform and the mixture then passed through a single thickness of fine quantitative filter paper. This process of filtration was repeated on the mixture using fresh filter papers each time, until no residue was deposited on the paper after the final filtering. The residue left on the papers was boiled in chloroform to dissolve any of the soluble tar constituents that might be deposited with the free carbon. This mixture was also filtered a number of times until no appreciable residue was left on the filter papers. The chloroform was then distilled off from the two mixtures which were combined and considered to be carbon-free tar. Analyses and coking tests were made which indicated that the material extracted was nearly all free carbon.

DETERMINATION OF FREE CARBON IN TARS.

The percentage of free carbon in each of the tars was determined to the nearest one-half of 1 per cent by careful quantitative filtering, employing a heavily matted Gooch crucible. After filtration was practically completed, the residue in the crucible was washed with chloroform until there was no further coloration of the liquid.

SPECIFIC GRAVITIES.

Specific gravities were determined by means of a Westphal balance. These determinations were accurate to one in the third decimal place for creosote and most of the mixtures of tar and creosote, and to two or three in the third decimal place for the heaviest tars.

VISCOSITIES.

The viscosities were determined by means of an Engler viscosimeter, which was standardized with water at 20° C.

Analyses of creosotes used in the experiments.

Creosote No. 1.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
205	11.0
235	28.3
245	5.1
275	9.7
305	13.1
320	6.9
Residue	25.8
Loss	0.1
Total	100.0

Specific gravity, 1.0483 at 60° C. The index of refraction values are low for coal-tar creosote, and the water content is high, being 8.4 per cent of the original oil. The residue indicates the presence of undistilled tar, probably about 10 per cent.

Creosote No. 2.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
205	6.8
235	40.0
245	4.5
275	13.4
305	11.0
Residue	24.1
Loss	0.2
Total	100.0

Specific gravity, 1.0475 at 60° C. The distillation curve and the index of refraction values for the most part fall within the range ascribed to a pure coal-tar creosote, but there is a decided tendency in the index of refraction values for the higher fractions, which indicates the presence of petroleum-like substances.

Creosote No. 3.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
205	4.6
235	27.4
245	5.1
285	21.3
305	11.6
360	22.7
Residue	7.0
Loss	0.3
Total	100.0

Specific gravity, 1.0576 at 60° C. The index of refraction values and the distillation curve indicate that the oil is a pure coal-tar creosote.

Creosote No. 4.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
205	1.2
235	22.7
245	5.7
275	9.9
305	11.5
360	27.6
Residue	20.9
Loss	0.5
Total	100.0

Specific gravity, 1.071 at 60° C. The indices of refraction at 60° C. are very low for a pure coal-tar creosote. The sulphonation values are low, yet are an indication of the presence of petroleum oils. The residue is a soft sticky pitch and indicates the presence of undistilled tar probably less than 5 per cent. From the appearance and physical properties of the fractions the creosote behaves very much like a mixed creosote.

Creosote No. 5.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
205	1.3
235	2.2
245	1.8
275	7.1
305	14.2
360	40.4
Residue	32.8
Loss	0.2
Total	100.0

Specific gravity, 1.105 at 60° C. The index of refraction values are almost entirely in the range for mixed creosotes. The sulphonation residues do not indicate the presence of paraffine oils. The nature of the residue is not such as to show the presence of undistilled tar. The appearance and physical properties of the fractions indicate a high boiling creosote oil.

Creosote No. 6.—The distillation is as follows:

Temperature.	Distillation.
°C.	*Per cent.*
180	2.0
235	37.7
245	5.2
275	9.5
305	11.7
330	8.6
Residue	25.0
Loss	0.3
Total	100.0

Specific gravity, 1.047 at 60° C. The index of refraction values lie mostly in the range for mixed creosotes. The sulphonation residues are too high for a straight coal-tar creosote and their character is much like that of petroleum oils. The amount of residue above 330° is rather large, but there is no sign of undistilled tar in it.

TABLE 1.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of creosote No. 4 and carbon-free by-product coke-oven tar No. 1 (normal amount of free carbon in tar, 6 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 1.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter).			
		P. ct. by volume.	*P. ct. by volume.*	*P. ct. by weight.*			*Lbs.*	*Lbs.*	*Ins.*
19A	13.0	0	100	Trace.	1.071	1.2	4.970	0.250	7.00
35	17.5	0	100	Trace.	1.071	1.2	4.270	.195	6.05
Average	15.3							.223	6.53
28	12.0	25	75	Trace.	1.102	1.4	4,783	.168	5.00
23A	14.5	25	75	Trace.	1.102	1.4	4.800	.266	7.64
Average	13.3							.217	6.32
32	15.0	50	50	Trace.	1.127	1.6	4.458	.122	4.34
22A	15.0	50	50	Trace.	1.127	1.6	4.825	.107	4.44
Average	15.0							.115	4.39
29	11.5	75	25	Trace.	1.150	2.3	4.504	.090	3.25
24A	13.0	75	25	Trace.	1.150	2.3	4.677	.119	4.05
Average	12.3							.105	3.65
30	13.5	100	0	Trace.	1.182	3.6	4.566	.069	4.19
20A	16.5	100	0	Trace.	1.182	3.6	4.463	.055	2.76
Average	15.0							.062	3.48

Average moisture in specimens about 2 per cent.

TABLE 2.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of creosote No. 4 and carbon-free by-product coke-oven tar No. 2 (normal amount of free carbon in tar, 16 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 2.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter).			
		P. ct. by volume.	*P. ct. by volume.*	*P. ct. by weight.*			*Lbs.*	*Lbs.*	*Ins.*
C-6	13.0	0	100	Trace.	1.071	1.2	4.059	0.241	7.31
B-5	15.0	0	100	Trace.	1.071	1.2	4.506	.139	4.25
Average	14.0							.190	5.78
C-4	13.0	25	75	Trace.	1.105	1.4	4.132	.103	3.89
B-6	14.0	25	75	Trace.	1.105	1.4	4.237	.167	4.71
Average	13.5							.135	4.30
C-5	14.5	50	50	Trace.	1.132	1.7	4.109	.111	4.34
B-3	14.0	50	50	Trace.	1.132	1.7	4.220	.089	3.68
Average	14.3							.100	4.01
C-3	11.0	75	25	Trace.	1.163	2.2	4.175	.041	2.71
B-2	13.0	75	25	Trace.	1.163	2.2	4.185	.033	1.90
Average	12.0							.037	2.31
C-2	9.0	100	0	Trace.	1.215	3.1	4.216	.035	1.25
B-1	16.0	100	0	Trace.	1.215	3.1	3.070	.021	1.42
Average	12.5							.028	1.34

Average moisture in specimens about 4.5 per cent.

TABLE 3.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of creosote No. 4 and carbon-free gas-house tar No. 3 (normal amount of free carbon in tar, 30 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 3.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter).			
		Per cent by volume.	*Per cent by volume.*	*Per cent by weight.*			*Lbs.*	*Lbs.*	*Ins.*
A-F-4	21.0	0	100	Trace.	1.071	1.2	4.272	0.117	5.55
A-E-3	21.0	0	100	Trace.	1.071	1.2	4.124	.121	4.65
Average	21.0							.119	5.10
A-F-2	20.0	25	75	Trace.	1.097	1.4	4.219	.054	3.62
A-E-6	22.0	25	75	Trace.	1.097	1.4	4.626	.054	3.20
Average	21.0							.054	3.41
A-F-1	20.0	50	50	Trace.	1.127	1.6	3.855	.015	1.60
A-E-7	20.0	50	50	Trace.	1.127	1.6	3.750	.014	1.43
Average	20.0							.015	1.52
A-F-5a	21.0	75	25	Trace.	1.148	2.3	2.063	.010	1.00
A-E-5a	19.0	75	25	Trace.	1.148	2.3	2.096	.011	1.15
Average	20.0							.011	1.08
A-E-2a	20.0	100	0	Trace.	1.179	3.8	1.697	.012	1.15
A-F-3a	22.0	100	0	Trace.	1.179	3.8	1.990	.007	.75
Average	21.0							.010	.95

Average moisture in specimens about 9 per cent.

TABLE 4.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of equal parts of creosote No. 4 and three different carbon-free and normal free-carbon tars.*

Specimen No.	Average number annual rings per inch.	Character of preservative.						Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar Nos. 1, 2, and 3.		Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler vicosimeter).			
		By volume.	Free carbon normal to tar.							
		Per cent.	*Per cent.*	*Per cent by volume.*	*Per cent by weight.*			*Lbs.*	*Lbs.*	*Ins.*
II-3	24.0	50	6	50	Trace.	1.127	1.6	1.443	0.127	3.75
III-2	18.0	50	6	50	Trace.	1.127	1.6	2.826	.200	4.19
Average	21.0								.164	3.97
II-8	17.0	50	16	50	Trace.	1.132	1.7	3.450	.130	4.30
III-5	20.0	50	16	50	Trace.	1.132	1.7	3.185	.080	3.12
Average	18.5								.105	3.71
II-5	22.0	50	30	50	Trace.	1.127	1.6	3.010	.053	2.27
III-1	17.0	50	30	50	Trace.	1.127	1.6	2.660	.076	2.18
Average	19.5								.065	2.23
II-2-B	18.0	50	6	50	3.0	1.132	1.7	1.420	.038	2.05
III-2-B	24.0	50	6	50	3.0	1.132	1.7	1.386	.054	2.00
Average	21.0								.046	2.03
II-1-A	22.0	50	16	50	8.0	1.159	2.6	1.410	.043	2.28
III-6-B	15.0	50	16	50	8.0	1.159	2.6	1.452	.029	1.54
Average	18.5								.036	1.91
II-4-A	21.0	50	30	50	15.0	1.166	2.5	1.466	.027	1.15
III-2-A	18.0	50	30	50	15.0	1.166	2.5	1.318	.017	1.13
Average	19.5								.022	1.14

Average moisture in specimens about 8 per cent.

TABLE 5.—*Treatment of paving blocks with mixtures of creosote No. 4 and carbon-free tar No. 1.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic foot.*		*Pounds per square inch.*	*Hours.*	
1	7.65 by 3.82 by 4.0	2.685	16.8	Creosote	80	2	140
32	8.10 by 3.65 by 4.0	2.715	15.4	Creosote	80	3	220
Average			16.1				180
11	7.75 by 3.80 by 4.0	2.826	17.7	75 per cent creosote, 25 per cent tar.	80	$2\frac{1}{2}$	180
56	8.10 by 3.50 by 4.2	2.820	13.5	75 per cent creosote, 25 per cent tar.	80	$3\frac{1}{2}$	260
Average			15.6				220
26	7.95 by 3.62 by 4.0	2.560	14.3	50 per cent creosote, 50 per cent tar.	80	6	460
7	7.75 by 3.55 by 4.0	2.665	19.1	50 per cent creosote, 50 per cent tar.	80	4	300
Average			16.7				380
43	7.65 by 3.80 by 4.0	2.680	14.8	25 per cent creosote, 75 per cent tar.	(1)	$5\frac{1}{2}$	490
10	8.20 by 3.55 by 4.15	2.850	13.7	25 per cent creosote, 75 per cent tar.	(2)	6	565
Average			14.3				527
41	7.67 by 3.05 by 4.03	2.170	16.7	100 per cent tar	(2)	6	565
58	8.10 by 3.60 by 4.0	2.670	14.1	100 per cent tar	(3)	$6\frac{1}{2}$	640
Average			15.4				602

[1] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; ½ hour at 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1 hour at 150 pounds.
[3] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1½ hours at 150 pounds.

In all tests ½ hour was taken to obtain pressure up to 80 pounds.

TABLE 6.—*Treatment of paving blocks with mixtures of creosote No. 4 and carbon-free tar No. 2.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic foot.*		*Pounds per square inch.*	*Hours.*	
21	7.65 by 3.80 by 4.0	2.880	17.4	75 per cent creosote, 25 per cent tar.	80	3	220
22	8.05 by 3.62 by 4.0	2.655	13.7	75 per cent creosote, 25 per cent tar.	80	$4\frac{1}{2}$	340
Average			15.6				280
23	7.75 by 4.0 by 4.0	2.970	17.6	50 per cent creosote, 50 per cent tar.	80	$5\frac{1}{2}$	420
60	8.00 by 4.2 by 3.5	2.780	14.7	50 per cent creosote, 50 per cent tar.	(1)	6	565
Average			16.2				492
37	7.75 by 3.90 by 4.0	3.090	14.5	25 per cent creosote, 75 per cent tar.	(1)	5	415
4	8.15 by 3.60 by 4.0	2.720	13.2	25 per cent creosote, 75 per cent tar.	(2)	$6\frac{1}{2}$	640
Average			13.9				527
5	7.70 by 3.95 by 4.0	2.955	19.4	100 per cent tar	(3)	$5\frac{3}{4}$	527
9	8.20 by 3.58 by 4.0	2.880	14.1	100 per cent tar	(4)	7	715
Average			16.8				621

[1] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1 hour at 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1½ hours at 150 pounds.
[3] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; ¾ hour at 150 pounds.
[4] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2 hours at 150 pounds.

In all tests ½ hour was taken to obtain pressure up to 80 pounds.

TABLE 7.—*Treatment of paving blocks with mixtures of creosote No. 4 and carbon-free gas-house tar No. 3.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic foot.*		*Pounds per square inch.*	*Hours.*	
3	7.71 by 3.77 by 4.0	2.770	16.1	75 per cent creosote, 25 per cent tar.	80	3½	260
34	8.15 by 3.62 by 4.15	2.820	12.4		80	4½	340
Average			14.3				300
57	7.75 by 3.45 by 4.0	2.580	19.0	50 per cent creosote, 50 per cent tar.	[1]	6½	640
52	8.15 by 3.55 by 4.2	2.880	12.2		[2]	7	715
Average			15.6				677
9	7.75 by 3.85 by 4.0	2.920	17.0	25 per cent creosote, 75 per cent tar.	[2]	7	715
44	8.15 by 3.60 by 4.1	2.855	9.6		[3]	7½	790
Average			13.3				752
29	7.75 by 3.10 by 4.0	2.335	18.6	100 per cent tar	[4]	7¾	827
6	7.95 by 3.60 by 4.0	2.660	11.9		[5]	8	865
Average			15.2				846

[1] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1½ hours at 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2 hours at 150 pounds.
[3] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2½ hours at 150 pounds.
[4] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2¾ hours at 150 pounds.
[5] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 3 hours at 150 pounds.

In all tests ½ hour was taken to obtain pressure up to 80 pounds.

TABLE 8.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of equal parts of creosote No. 4 and by-product coke-oven tar No. 1 with different amounts of free carbon (normal amount of free carbon in tar, 6 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 1.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter.			
		P. ct. by volume.	*P. ct. by volume.*	*P. ct. by weight.*			*Lbs.*	*Lbs.*	*Ins.*
K-4	22.0	50	50	Trace.	1.127	1.6	4.008	.200	5.20
R-5	15.0	50	50	Trace.	1.127	1.6	3.444	.151	3.98
Average	18.5							.176	4.89
K-6	23.0	50	50	1	1.128	1.7	4.180	.122	4.55
R-2	17.0	50	50	1	1.128	1.7	3.250	.130	3.50
Average	20.0							.126	4.03
K-3	21.0	50	50	1.5	1.129	1.7	3.616	.100	3.97
R	16.0	50	50	1.5	1.129	1.7	1.444	.087	2.73
Average	18.5							.094	3.35
K-7	21.0	50	50	2.5	1.130	1.5	4.390	.098	3.82
R-3	16.0	50	50	2.5	1.130	1.5	3.312	.078	2.80
Average	18.5							.088	3.31
K-5	20.0	50	50	3	1.132	1.7	4.095	.063	3.12
R-7	16.0	50	50	3	1.132	1.7	3.783	.060	2.73
Average	18.0							.062	2.93

Average moisture in specimens about 11 per cent.

TABLE 9.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of equal parts of creosote No. 4 and by-product coke-oven tar No. 2 containing different amounts of free carbon (normal amount of free carbon in tar, 16 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 2.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter).			
		P. ct. by volume.	*P. ct. by volume.*	*P. ct. by weight.*			*Lbs.*	*Lbs.*	*Ins.*
F-4	16.5	50	50	Trace.	1.132	1.7	4.021	0.071	2.61
G-5	15.0	50	50	Trace.	1.132	1.7	4.115	.025	1.39
Average	15.8							.048	2.00
F-1	17.0	50	50	3	1.140	1.9	4.178	.064	2.82
G-2	16.0	50	50	3	1.140	1.9	4.376	.016	1.10
Average	16.5							.040	1.96
F-3	16.0	50	50	5	1.147	1.9	4.123	.049	2.45
G-1	16.5	50	50	5	1.147	1.9	4.280	.012	.80
Average	16.3							.031	1.63
F-7	16.0	50	50	6.5	1.152	2.0	4.198	.050	2.43
G-3	17.0	50	50	6.5	1.152	2.0	4.315	.009	.80
Average	16.5							.029	1.62
F-6	17.0	50	50	8	1.159	2.6	4.135	.047	2.00
G-7	16.0	50	50	8	1.159	2.6	[1]1.673	.008	1.15
Average	16.5							.027	1.58

[1] Short specimen.

Average moisture in specimens about 5 per cent.

TABLE 10.—*Data upon the relative absorptions and penetrations into longleaf pine of mixtures of equal parts of creosote No. 4 and tar No. 3 containing different amounts of free carbon (normal amount of free carbon in tar, 30 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		Tar No. 3.	Creosote No. 4.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at 160° F. (Engler viscosimeter).			
		P. ct. by volume.	*P. ct. by volume.*	*P. ct. by weight.*			*Lbs.*	*Lbs.*	*Ins.*
II-7	14.0	50	50	Trace.	1.127	1.6	[1]1.580	.053	3.16
H-4	15.0	50	50	Trace.	1.127	1.6	4.187	.029	2.82
Average	14.5							.041	2.99
II-5	14.0	50	50	4.5	1.133	1.7	4.665	.045	2.30
H-1	12.0	50	50	4.5	1.133	1.7	[1]1.667	.023	1.69
Average	13.0							.034	2.00
II-4	12.0	50	50	6	1.142	1.9	4.453	.019	2.25
H-7	12.0	50	50	6	1.142	1.9	4.357	.007	1.13
Average	12.0							.013	1.69
II-4A	12.0	50	50	8	1.146	2.0	[1]1.704	.031	1.50
H-6	13.0	50	50	8	1.146	2.0	4.097	.010	1.25
Average	12.5							.021	1.38
II-7A	14.0	50	50	12	1.152	2.5	4.407	.037	2.54
H-5	13.5	50	50	12	1.152	2.5	4.040	.007	1.18
Average	13.8							.022	1.86
II-3	14.0	50	50	15	1.166	2.5	[1]1.826	.038	3.00
H-3	13.0	50	50	15	1.166	2.5	1.664	.016	1.39
Average	13.5							.027	2.20

[1] Short specimens.

Average moisture in specimens about 6 per cent.

TABLE 11.—*Treatments of paving blocks with 50 per cent creosote No. 4 and 50 per cent tar No. 1 having varying percentages of carbon.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic feet.*		*Pounds per square inch.*	*Hours.*	
19	7.70 by 3.75 by 4.0	2.830	15.0	50 per cent creosote	80	4	300
30	8.15 by 3.50 by 4.2	2.860	14.8	50 per cent tar with 1½ per cent carbon.	[1]		495
Average			14.9				397
49	7.70 by 3.84 by 4.0	2.855	16.2	50 per cent creosote	80	5	380
54	8.20 by 3.60 by 4.15	2.900	15.2	50 per cent tar with 3 per cent carbon.	[2]	5½	490
Average			15.7				435

[1] Five hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; one-half hour at 150 pounds.

In all tests one-half hour was taken to obtain pressure up to 80 pounds.

TABLE 12.—*Treatment of paving blocks with 50 per cent creosote No. 4 and 50 per cent tar No. 2 having varying percentages of carbon.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic feet.*		*Pounds per square inch.*	*Hours.*	
35	7.65 by 3.80 by 4.0	2.760	16.1	50 per cent creosote	80	6	460
38	8.15 by 3.60 by 4.0	2.740	15.3	50 per cent tar with 5 per cent carbon.	(1)	6½	640
Average			15.7				550
33	7.65 by 3.80 by 4.0	2.750	17.7	50 per cent creosote	(2)	5	415
48	8.10 by 3.62 by 4.0	2.690	14.9	50 per cent tar with 10 per cent carbon.	(3)	7½	790
Average			16.3				602
2	8.15 by 3.62 by 4.0	2.790	16.5	50 per cent creosote	(4)	8	865
39	7.68 by 3.80 by 4.0	2.760	16.8	50 per cent tar with 16 per cent carbon.	80	5½	420
Average			16.7				642

In all tests one-half hour was taken to obtain pressure up to 80 pounds.

[1] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 1½ hours at 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds.
[3] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2½ hours at 150 pounds.
[4] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 3 hours at 150 pounds.

TABLE 13.—*Treatment of paving blocks with 50 per cent creosote No. 4 and 50 per cent tar No. 3 having varying percentages of carbon.*

Block tag No.	Dimensions of block.	Weight before treatment.	Preservative absorbed.	Preservative used.	Pressure.	Time of treatment.	Product of pressure by time.
	Inches.	*Pounds.*	*Pounds per cubic feet.*		*Pounds per square inch.*	*Hours.*	
27	7.70 by 3.85 by 4	3.150	17.2	50 per cent creosote	(1)	7	715
20	8.20 by 3.55 by 4	3.180	13.9	50 per cent tar with 9 per cent carbon.	(2)	7½	790
Average			15.6				752
15	7.75 by 3.85 by 4	3.220	18.5	50 per cent creosote	(2)	7½	790
50	8.13 by 3.62 by 4	2.700	10.3	50 per cent tar with 16 per cent carbon.	(3)	7¾	827
Average			14.4				808
53	7.70 by 3.95 by 4	2.930	20.8	50 per cent creosote	(2)	7½	790
28	8.20 by 3.60 by 4.2	2.980	8.8	50 per cent tar with 24 per cent carbon.	(4)	7¾	810
Average			14.8				800
51	7.70 by 3.10 by 4	2.345	20.7	50 per cent creosote	(5)	7¼	752
40	7.93 by 3.62 by 4	2.605	10.8	50 per cent tar with 30 per cent carbon.	(3)	7¾	827
Average			15.8				789

[1] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2 hours at 150 pounds.
[2] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2½ hours at 150 pounds.
[3] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2¾ hours at 150 pounds.
[4] Four and a half hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2½ hours at 150 pounds.
[5] Four hours at 80 pounds; 1 hour to obtain pressure up to 150 pounds; 2¼ hours at 150 pounds.

In all tests one-half hour was taken to obtain pressure up to 80 pounds.

TABLE 14.—*Data upon the relative absorptions and penetrations into longleaf pine of five different commercial creosotes.*

Specimen No.	Average number annual rings per inch.	Character of preservative.	Specific gravity at 60° C.	Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
				Pounds.	*Pounds.*	*Inches.*
V-1	19.0	Creosote No. 1 containing tar (estimated at about 10 per cent).	1.0483	3.493	0.072	3.58
A-D-8	8.0			4.517	.107	4.72
Average	13.5				.090	4.15
V-4	19.0	Creosote No. 2	1.0475	3.118	.152	6.58
A-D-2	6.0			3.801	.292	8.72
Average	12.5				.222	7.65
V-7	21.0	Pure coal-tar creosote No. 3	1.0576	3.120	.170	7.18
A-D-10	5.0			4.291	.249	8.66
Average	13.0				.210	7.92
V-5	20.0	Creosote containing tar No. 4 (estimated at less than 5 per cent).	1.071	3.010	.090	3.80
A-D-1	5.0			3.976	.224	7.60
Average	12.5				.157	5.70
V-8	21.0	High-boiling creosote No. 5	1.105	3.078	.076	3.73
A-D-3	5.0			4.828	.096	5.26
Average	13.0				.086	4.50

Average moisture in specimens about 6 per cent.

TABLE 15.—*Showing the effect on absorption and penetration when varying mixtures of tar No. 4 and creosote No. 6 are used.*

Specimen No.	Length.	Breadth.	Depth.	Weight before treatment.	Absorption.	Preservative used.	Pressure per square inch.	Time of treatment.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*		*Pounds.*	*Hours.*
D-1	23.05	3.50	1.50	2.590	0.130			
E-4	24.20	3.55	1.55	2.780	.190	Creosote	80	2
F-5	23.15	3.50	1.50	2.610	.195			
Average					.172			
D-2	23.15	3.50	1.50	3.027	.070	80 per cent creosote		
E-2	24.20	3.50	1.50	2.698	.166	20 per cent tar	80	2
F-3	23.05	3.50	1.50	2.596	.138			
Average					.125			
D-3	14.40	3.50	1.50	1.923	.057	66⅔ per cent creosote		
E-6	24.20	3.50	1.50	2.920	.180	33⅓ per cent tar	80	2
F-2	23.05	3.50	1.50	2.607	.103			
Average					.113			

Specimen No.	Area penetrated.	Average longitudinal penetration.	Number of annual rings.	Depth of hole.	Preservative used.
	Sq. in.			*Inches.*	
D-1	10.8	4.9	14	1.00	
E-4	19.0	9.1	12	.99	Creosote.
F-5	13.1	6.0	14	1.00	
Average		6.7			
D-2	8.4	3.7	16	1.00	80 per cent creosote, 20 per cent tar.
E-2	15.1	7.0	12	1.00	
F-3	9.0	4.0	18	1.00	
Average		4.9			
D-3	7.5	3.2	17	1.00	66⅔ per cent creosote.
E-6	15.4	7.2	12	1.00	33⅓ per cent tar.
F-2	8.0	3.5	18	1.00	
Average		4.6			

It was not possible to get enough matched specimens from one stick for the three treatments. Three sticks were used and one specimen taken from each stick for each preservative.

Average moisture 8 per cent to 10 per cent.

TABLE 16.—*Showing the variation in: (1) Time of treatment, and (2) pressure necessary to secure a given absorption when varying mixtures of tar No. 4 and creosote No. 6 are used at a temperature of 160° F.*

Specimen No.	Length.	Breadth.	Depth.	Weight before treatment.	Absorption.	Preservative used.	Time of treatment.	Pressure.	Area penetrated.	Average longitudinal penetration.	Number of annual rings.	Depth of hole.
	Inches.	*Inches.*	*Inches.*		*Pounds.*		*Hours.*	*Lbs. per sq. in.*				
A-2	24.20	3.45	1.50	3.036	.074				17.7	8.35	10.0	1.00
B-1	24.20	3.40	1.50	3.210	.137	Creosote	2	80	21.4	10.20	15.0	1.00
C-6	20.30	3.48	1.50	2.287	.283				18.0	8.50	15.0	1.00
Average					.165					9.02		
A-5	24.20	3.45	1.40	2.860	.068		$4\frac{1}{4}$		14.0	6.37	10.0	1.02
B-2	24.20	3.45	1.45	2.995	.135	80 per cent creosote	5	80	15.5	7.25	15.0	1.00
C-7	20.35	3.45	1.50	2.210	.290	20 per cent tar	$2\frac{1}{12}$		18.5	8.75	15.0	1.00
Average					.164					7.46		
A-1	24.20	3.45	1.45	3.014	.046	$66\frac{2}{3}$ per cent creosote	[1] $6\frac{1}{2}$		8.0	3.75	10.0	1.00
B-3	24.15	3.45	1.45	2.920	.065		[2] 8	80	12.0	5.50	15.5	1.00
C-3	20.30	3.45	1.50	2.447	.288	$33\frac{1}{3}$ per cent tar	[3] $4\frac{1}{2}$		18.0	8.69	12.0	.98
Average					.133					5.98		
A-3	24.20	3.45	1.40	2.873	.057	80 per cent creosote		115	14.5	6.75	11.0	1.00
B-7	24.20	3.45	1.45	2.808	.092	20 per cent tar		155	10.0	4.50	19.0	1.00
C-4	20.35	3.50	1.45	2.300	.320		2	115	17.9	8.45	13.0	1.00
Average					.156					6.57		
A-6	24.20	3.45	1.45	2.825	.075	$66\frac{2}{3}$ per cent creosote		155	12.0	5.50	10.0	1.00
B-5	24.20	3.45	1.50	2.827	.083			155	12.3	5.65	10.0	1.00
C-2	20.25	3.45	1.50	2.440	.310	$33\frac{1}{3}$ per cent tar	2	150	17.0	8.00	16.0	1.00
Average					.156					6.38		

[1] The absorption given was obtained in about $5\frac{1}{2}$ hours' treatment.
[2] The absorption given was obtained in about $6\frac{1}{2}$ hours' treatment.
[3] The absorption given was obtained in about 4 hours' treatment.
The further increase in time of treatment did not increase the absorption.

NOTE 1.—It was necessary to use three different sticks to secure enough specimens for the tests. One specimen from each stick was used in each treatment. The three sticks in each treatment were, therefore, not matched with each other.

NOTE 2.—The average moisture content varied between 8 and 10 per cent.

TABLE 17.—*Summary of data contained in Table 16.*

Preservative.	Average time of treatment.	Average absorption.	Average pressure.	Average longitudinal penetration.	Absorption obtained.	Penetration obtained.	Increase in pressure.	Increase in time.
	Hours.	*Pounds.*	*Pounds per sq. in.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Creosote	2	0.165	80	9.02	100	100	0	[1] 0
80 per cent creosote; 20 per cent tar	4.05	.164	80	7.46	99	83	0	[1] 102
66⅔ per cent creosote; 33⅓ per cent tar	6.33	[2] .133	80	5.98	81	66	0	[1] 217
80 per cent creosote; 20 per cent tar	2	.156	128	6.57	95	73	60	[3] 0
66⅔ per cent creosote; 33⅓ per cent tar	2	.156	155	6.38	95	71	94	[3] 0

[1] Time varied.
[2] This absorption was obtained with an average of about 5½ hours' treatment. The further increase in the time of treatment failed to increase the absorption.
[3] Pressure varied.

See Note 1, Table 16.

TABLE 18.—*Data upon the relative absorptions and penetrations into longleaf pine of a mixture of equal parts of creosote No. 4 and a normal by-product coke-oven tar No. 1 at different temperatures (normal amount of free carbon in tar 6 per cent, by weight).*

Specimen No.	Average number annual rings per inch.	Temperature.	Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.
		°F.	*Pounds.*	*Pounds.*	*Inches.*
IX-6	12.0	160	2.570	0.046	2.98
VII-1	8.0	160	2.630	0.039	2.92
Average	10.0			0.042	2.95
IX-3	9.0	180	2.605	0.045	3.00
VII-3	11.0	180	2.635	0.075	4.23
Average	10.0			0.060	3.62
IX-1	11.0	190	2.728	0.038	3.18
VII-7	9.0	190	2.473	0.092	3.45
Average	10.0			0.065	3.32
IX-7	10.0	200	2.578	0.067	3.97
VII-4	8.0	200	2.615	0.103	4.76
Average	9.0			0.085	4.36
IX-2	10.0	210	2.480	0.094	4.76
VII-2	9.0	210	2.454	0.115	5.42
Average	9.5			0.104	5.09

Average moisture in specimens about 10 per cent.

TABLE 19.—*Data on absorption tests on paving blocks with tar and creosote mixtures.*

Block No.	Dimensions.	Volume.	Weight before treatment.	Weight 24 hours after treatment.	Absorption.	Preservative.	Time of treatment.	Temperature.	Pressure.	Viscosity at treating temperature.
	Inches.	*Cubic feet.*	*Pounds.*	*Pounds.*	*Pounds per cubic foot.*		*Minutes.*		*Pounds per square inch.*	
1	8.05 by 4.2 by 4.15	0.081	3.88	5.03	14.2					
2	8.10 by 4.2 by 4.2	0.083	4.03	5.43	16.9					
3	8.10 by 4.25 by 4.15	0.083	3.85	5.10	15.1	Creosote (specific gravity at 60° C. 1.071)	40	180	100	1.15
4	8.10 by 4.2 by 4.15	0.082	3.93	5.10	14.3					
Average					15.1					
9	8.1 by 4.3 by 4.1	0.083	3.67	4.97	15.7					
10	8.1 by 4.25 by 4.1	0.082	3.82	5.05	15.0					
11	8.0 by 4.2 by 4.15	0.081	3.78	5.13	16.7	Creosote	25	220	200	1.10
12	8.1 by 4.25 by 4.05	0.081	3.66	4.92	15.6					
Average					15.8					
13	8.0 by 4.2 by 4.2	0.082	3.79	5.04	15.2					
14	8.1 by 4.05 by 4.2	0.080	3.62	4.84	15.3					
15	8.1 by 4.2 by 4.15	0.082	3.76	4.94	14.4	Creosote	120	160	75	1.20
16	8.1 by 4.2 by 4.3	0.085	4.10	5.50	16.5					
Average					15.4					
25	8.05 by 4.15 by 4.25	0.082	4.05	5.66	19.7	75 per cent creosote				
26	8.1 by 4.05 by 4.2	0.080	3.60	4.94	16.7	25 per cent tar				
27	8.1 by 4.2 by 4.1	0.081	3.73	5.10	16.9	Mixture (specific gravity at 60° C. 1.086)	30	220	200	1.33
28	8.1 by 4.15 by 4.1	0.080	3.69	4.98	16.1					
Average					17.3					
29	8.0 by 4.15 by 4.15	0.080	3.71	4.98	15.9	50 per cent creosote				
30	8.0 by 4.1 by 4.25	0.081	4.04	5.48	17.8	50 per cent tar				
31	8.1 by 4.1 by 4.2	0.081	3.65	4.77	13.8	Mixture (specific gravity at 60° C. 1.109)	40	220	200	1.42
32	8.1 by 4.15 by 4.25	0.083	4.05	5.30	15.1					
Average					15.6					
37	8.1 by 4.25 by 4.2	0.084	4.00	5.24	14.8	25 per cent creosote				
38	8.1 by 4.1 by 4.25	0.082	3.65	5.00	16.5	75 per cent tar				
39	8.1 by 4.2 by 4.25	0.084	4.05	5.41	16.2	Mixture (specific gravity at 60° C. 1.149)	75	220	200	1.60
40	8.1 by 4.15 by 4.1	0.080	3.59	4.96	17.1					
Average					16.2					

TABLE 20.—*Penetrance tests on longleaf pine with mixtures of tar No. 5 and creosote No. 4.*

Specimen No.	Average number annual rings per inch.	Moisture per cent, (average).	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed	Average longitudinal penetration.	Time of treatment.	Temperature.	Pressure.
			Tar No. 5.	Creosote.	Free carbon in mixture.	Specific gravity at 140° F. (60° C.)	Viscosity at treating temperature.						
			Per cent by volume.	*Per cent by volume.*	*Per cent by weight.*			*Pounds.*	*Pounds.*	*Inches.*	*Minutes.*	*° F.*	*Pounds per square inch.*
1-1	19	9.3	.....	100	.....	1.071	1.15	3.950	0.036	2.83	40	180	100
2-1	9							3.475	0.005	1.23	40	180	100
3-1	10							3.222	0.018	1.30	40	180	100
4-1	9							3.105	0.019	1.50	40	180	100
									0.0195	1.72			
1-5	19	2.2	.....	100	.....	1.071	1.10	3.380	0.190	6.83	25	220	200
2-5	9							3.115	0.085	3.50	25	220	200
3-5	11							3.094	0.041	2.37	25	220	200
4-5	9							3.100	0.100	3.17	25	220	200
									0.104	3.97			
1-7	18	9.5	.....	100	.....	1.071	1.2	3.586	0.107	6.50	120	160	75
2-7	10							3.000	0.015	2.50	120	160	75
3-7	8							3.223	0.017	2.03	120	160	75
4-7	11							3.087	0.013	2.17	120	160	75
									0.038	3.30			
1-2	18	5.6	25	75	3.6	1.086	1.33	3.516	0.164	6.00	30	220	200
2-2	9							3.366	0.042	2.50	30	220	200
3-2	10							3.236	0.064	3.50	30	220	200
4-2	10							3.045	0.059	2.37	30	220	200
									0.082	3.59			
1-3	18	10.2	50	50	7.1	1.109	1.42	3.568	0.102	3.83	40	220	200
2-3	10							3.066	0.054	2.50	40	220	200
3-3	11							3.320	0.044	3.83	40	220	200
4-3	11							2.918	0.052	2.50	40	220	200
									0.063	3.16			
1-4	17	5.3	75	25	10.9	1.149	1.60	3.550	0.085	4.17	75	220	200
2-4	12							2.970	0.060	2.17	75	220	200
3-4	10							3.100	0.080	2.50	75	220	200
4-4	10							3.090	0.074	2.85	75	220	200
	11.7								0.075	2.92			

TABLE 21.—*Data upon the relative penetration and absorption into longleaf pine of a mixture of 25 per cent creosote No. 4 and 75 per cent tar No. 5 at different treating tempertures (normal amount of free carbon in the tar 14 per cent by weight).*

Specimen No.	Average number annual rings per inch.	Moisture.	Character of preservative.					Weight of specimen directly before treatment.	Preservative absorbed.	Average longitudinal penetration.	Time of treatment.	Temperature.	Pressure.
			Tar No. 5.	Creosote.	Free carbon in mixture.	Specific gravity at 140° F.) (60° C.	Viscosity at treating temperature.						
		Per cent.	*Per cent by volume.*	*Per cent by volume.*	*Per cent by weight.*			*Pounds.*	*Pounds.*	*Inches.*	*Minutes.*	° *F.*	*Pounds per square inch.*
5-1	18	2.0	75	25	10.9	1.149	1.60	3.910	0.066	2.83	60	220	200
6-1	10							3.125	0.080	3.17	60	220	200
7-1	18							3.895	0.045	2.17	60	220	200
									0.064	2.72			
5-3	19	6.0	75	25	10.9	1.149	2.50	3.888	0.062	3.50	60	190	200
6-3	10							3.290	0.032	2.17	60	190	200
7-3	17							4.370	0.050	1.67	60	190	200
									0.048	2.45			
5-2	20	6.4	75	25	10.9	1.149	5.00	4.243	0.017	1.17	60	160	200
6-2	13							3.280	0.035	1.70	60	160	200
7-2	16							3.905	0.025	1.50	60	160	200
									0.026	1.46			

TABLE A.—*Showing composition of treating oil.*

(See penetrance specimens on Pl. IV.)

Piece No.	Creosote No. 4, per cent of total oil by volume.	Tar No. 3, per cent of total oil by volume.	Free carbon, per cent of total oil by weight.
1	0	100	Trace.
2	25	75	Trace.
3	50	50	Trace.
4	75	25	Trace.
5	100	0	Trace.

TABLE B.—*Showing composition of treating oil.*

(See penetrance specimens on Pl. V.)

Piece No.	Creosote No. 4, per cent of total oil by volume.	Tar.		Free carbon, per cent of total oil by weight.	Tar No.
		Per cent of total oil by volume.	Amount of carbon normal to the tar, per cent of total weight of tar.		
1	50	50	6	Trace.	1
2	50	50	16	Trace.	2
3	50	50	30	Trace.	3
4	50	50	6	3	1
5	50	50	16	8	2
6	50	50	30	15	3

TABLE C.—*Showing composition of treating oil.*

(See penetrance specimens on Pl. VI.)

Piece No.	Creosote No. 4, per cent of total oil by volume.	Tar No. 2, per cent of total oil by volume.	Carbon per cent by weight.
1	50	50	Trace.
2	50	50	3
3	50	50	5
4	50	50	6.5
5	50	50	8

TABLE D.—*Treating oil.*

(See penetrance specimens on Pl. VII.)

Piece No.	Creosote No.	Treating oil.
1	1	Creosote containing tar (estimated at about 10 per cent).
2	2	Creosote.
3	3	Pure coal-tar creosote.
4	4	Creosote containing tar (estimated at less than 5 per cent).
5	5	High-boiling creosote.

TABLE E.—*Showing temperature of treatment.*

(See penetrance specimens on Pl. XI.

Piece No.	Temperature of treatment.
1	160
2	180
3	190
4	200
5	210

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